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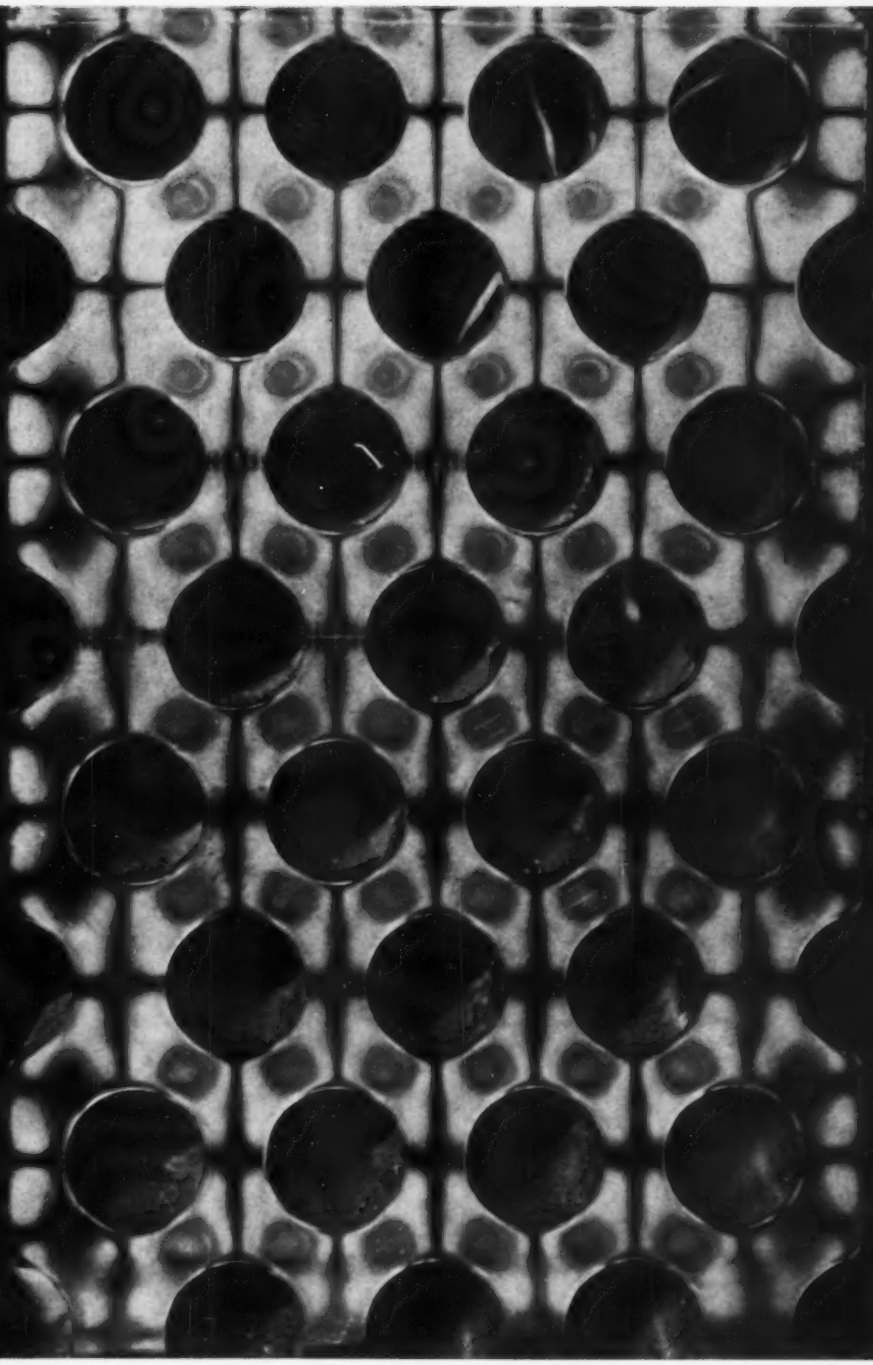

METAL PROGRESS

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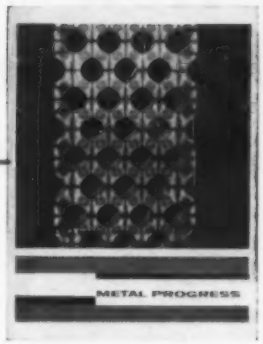
Circle 1910 on Page 48-B

Metal Progress

November 1960 . . . Volume 78, No. 5



Nicknamed the "Swiss cheese cover" by the editorial staff, this month's design is a photograph, taken through a polariscope at Southwest Research Institute, of the stress pattern in a perforated aluminum plate. Complete details on p. 111.

Technical News in Brief

Fluid Bed Marks New Gain in Heat Treating . . . Belt Grinding Takes Role in Precision Finishing . . . Survey Predicts Bright Future for Stainless Steel . . . Aluminum Applied to Steel by Vapor Deposition . . . More Interest in Direct Iron Processes . . . Quartz-Tube Furnaces Aid Missile Research . . . Uses for Depleted Uranium . . . Cold Working Improves Powder Metal Compacts . . . Materials Progress in Graphite and Ceramics . . . Silicon May Not Cause Decarburization 65

Progress in High-Temperature Materials

How to Fabricate René 41, by Louis A. Weisenberg and Robert J. Morris 70

One of the newest of the superalloys, this nickel-base alloy can retain high strength above 1400° F. Details on heat treating, welding and brazing are given. (J27, K-general; Ni-b, SGA-h)

Brazing René 41, by G. S. Hoppin III 75

Three brazing alloys have been devised; each answers specific needs. The type producing the strongest joints (J-8600) is used to braze uncoated alloys in a vacuum; the others will braze nickel-plated René 41 in hydrogen. (K8; Ni-b, SGA-h)

Refractory Metals for Air and Space Vehicles, Reported by R. H. Gassner 80

Discussions at a recent West Coast conference. Most of the research so far has centered around molybdenum, columbium, tantalum and tungsten. Main drawback: at high temperatures, all of them have very low resistance to oxidation. (T24, Q-general; EG-d, SGA-h, 17-57)

New Science of Ceramics Takes Hold, Reported by W. W. Austin 88

Testing techniques pioneered by metals engineers are now being widely used to evaluate ceramic materials. At a recent conference in North Carolina, researchers presented significant information relating the mechanical behavior of ceramics to their fundamental structures. One result: Ceramics which are reasonably resistant to impact and heat up to 5000° F. appear to be in the offing. (Q-general, M-general; NM-f)

Engineering Articles

Forming Galvanized Sheet Steel, by Paul G. Nelson 93

Galvanized sheet – either differentially coated or protected only on one side – is receiving a great deal of attention because of its potential in auto bodies. Preliminary experience indicates that it can be formed as readily as uncoated steel but not with the same tooling. (G-general, F29s; ST, 8-65, Zn)

Formability Tests for Sheet Metal, by Tom Bishop 95

A cheap and rapid test which can be performed in the shop and which duplicates shop conditions is still unknown. The best that our present laboratory tests can do is to classify samples as to grades or quality levels. (Q23q, 1-54; 4-53)

Table of Contents Continued on Page 3

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

How service life of a furnace I-beam was increased 400%

Electro-Alloys' knowledge of thermal fatigue lead to a simple solution

As a result of cyclical heating and cooling, heat-treating equipment, trays, rolls, tubes and other furnace components, are particularly vulnerable to thermal fatigue. This failure mechanism is not easily spotted. Therefore, the natural course of user and supplier of heat-resistant castings is to try to strengthen the component through the addition of braces, gussets, tie rods and other restricting members or through making heavier metal sections.

Almost inevitably this procedure results in an even shorter service life. The reason: a greater number of design members and heavier metal sections accelerate thermal fatigue.

An interesting study in thermal fatigue and how it was minimized is shown in the Figures at the right.

I-beam was failing after 4-6 months

The beam, shown in Figure 1, supported tube stock heated for welded tubing. After 4-6 months service, the beam would crack and fail at Area "A".

Preliminary calculations proved that the beam was more than adequate in strength. Therefore, Electro-Alloys engineers concentrated their study on the thermal factors of the furnace operation. As shown in Figure 1, the burners were firing below the beam, and special precautions had been taken to insure that the burner flame did not impinge on the cast-alloy beam. But, as also shown, the flame traveling across the furnace strikes a slanted pier and deflects into the casting at Area A. The high concentration of heat at "A" causes the flange to expand more rapidly than the web. This condition created the failure shown in Figure 2 and in the photographic close-up, Figure 3.

To all intents, the failure had the implications of a weak beam . . . buckling, cracking and downward deformation. The approach to solving this problem could be to increase the metal sections or to add restricting members.

Simple baffle extends beam life 400%

Electro-Alloys solution of the problem was not the design of a new beam but the far simpler design of a loose baffle to fit the beam, see Figure 4. This baffle could take the thermal shock. It was small, flexible and could deform at will without detracting from the strength of the beam.

This simple baffle has lengthened beam life 400%.

Avoiding expensive thermal-fatigue pitfalls

Users and designers of heat-resistant castings are vulnerable, generally, to two pitfalls that lead to losses in service life and operating economy:

a. Too much faith in the calculation of applied stresses as the measure of the casting's ability to withstand service conditions. This is reflected by increasing the size or number of restricting members . . . braces, gussets and tie rods.

b. Assuming that an alloy operating well at 2000° F. will work just as well in a different application where maximum temperature is only 1700° F.

These pitfalls are a natural outgrowth of the lack of information on thermal fatigue, an important cause of heat-resistant casting failures.

Electro-Alloys is recognized as a leading authority on thermal fatigue and high-alloy casting design. Case histories, such as the one reported here, and the widely published test data emanating from the Research Laboratory at Mahwah, N. J., are evidence of this.

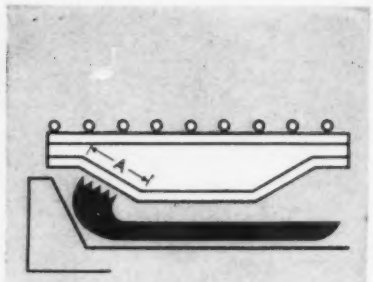


FIGURE 1

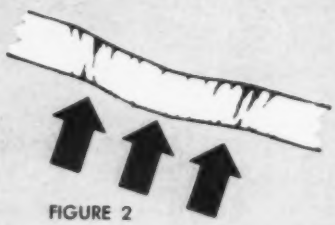


FIGURE 2

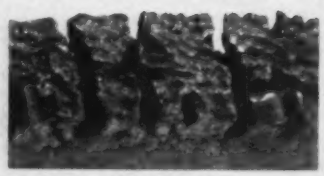


FIGURE 3

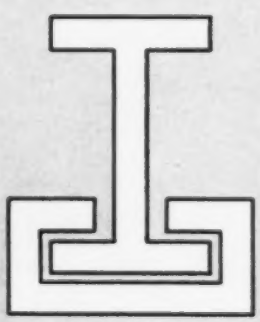


FIGURE 4

● *Most recent of these reports is "The Mechanism of Thermal Fatigue," by H. S. Avery. Copies of this study are available on request. Simply write to Electro-Alloys Division, 20111 Taylor Rd., Elyria, Ohio.*

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Metal Progress

Progress With 25% Nickel Steels for High-Strength Applications 99

Nickel steels containing 18 to 27% Ni have high strength and excellent cold working characteristics. Properties result from a combination of precipitation and transformation hardening. (A-general, Q-general; Fe-b, *Ni*, SGB-a)

Quenching in the Automatic Production Line, by O. E. Cullen 101

Factors involved in designing the quenching section of a heat treating line for automatic operation. To realize true economies, the engineer must balance the costs of new equipment against the savings which can result from less labor and lower rejection rate. (J26, 18-74)

Modified 4340, Heat Treated to 270,000 to 300,000 Ultimate, by J. C. Chang, F. J. Herr and J. W. Sweet 104

Steels made by three methods – basic electric, vacuum induction, and consumable arc – were studied and their longitudinal and transverse properties evaluated as well as their toughness and fatigue resistance both statically and dynamically. (Q-general, 3-70; AY)

Stress Analysis With a Photoelastic Coating, by Felix Zandman 111

Direct observation of the stress distribution of an actual part under load is possible with this coating technique. The direction and magnitude of principal stresses can be easily determined and test results can be recorded by color photography. (Q25, 1-54)

Electronic Metallurgy, by Harvey A. Anderson 119

The electronic industry, based on semiconductors, is growing at such an astonishing rate that it has outrun the available supply of metallurgists and solid-state physicists. Furthermore, quality control has all but outrun the ability to measure micro differences in the materials of construction. (T1, 17-57; EG-j, Si, Ge)

Critical Point

Modern Ceramics: Ally of Modern Metals 69

Atomic Age

The A.E.C.'s Power Program 118

Extracts from an address by F. K. Pittman, director of division of reactor development, U. S. Atomic Energy Commission, before World Power Conference, Madrid, Spain, June 8, 1960.

Short Runs

Navy Picks Cast Stainless Alloy, by E. A. Schoefer 122

Torpedo tube breech doors for nuclear submarines are being made of CD-4 MCu, a precipitation hardening stainless casting alloy which is stronger and more corrosion resistant than 18-8 steels. (T22; SS, 17-57)

Data Sheet

Hardenability Bands for Steels 6118-H to 8630-H 100-B

Book Review

Malleable Iron Castings, Reviewed by Carl F. Joseph 121

Correspondence

Trends in Price of High-Alloy Castings, by E. A. Schoefer 124

Chromium Steels in Refinery Service 124

Comments by R. W. Manuel, F. K. Zerbe, Kenneth G. Carroll and Merrill A. Scheil

Metals Engineering Digest

Mechanisms of Corrosion 170

Fatigue From Impact 190

Effect of Boron on "Weld Decay" 192

Departments

Press Breaks 5
New Products 21
New Literature 35
Personals 152
Behind the Bylines 216
Advertisers' Index 220

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PRESS BREAKS

While the Editor-in-Chief was looking at the TV report of Premier Khrushchev's speech at the United Nations, he bethought himself of these verses from the Proverbs:

> These six things doth the Lord hate: yea, seven are an abomination unto Him:
>
> A proud look, a lying tongue, and hands that shed innocent blood,
>
> An heart that deviseth wicked imaginations, feet that be swift in running to mischief,
>
> A false witness that speaketh lies, and he that soweth discord among brethren.

Salaries of Metallurgists

In 1957 Walter Morrison collected some data on the salaries of metallurgists belonging to the A.S.M. and summarized his results in *Metal Progress* for February 1958, p. 93. The Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers (A.I.M.E. to you) has published the results of a similar 1959 survey in the June issue of its *Journal of Metals*. As might be supposed the results are similar.

The curve for median salary versus age for 3393 members of A.I.M.E. who responded has the same trend as the average for ASMembers shown in Fig. 1 of Morrison's article and has a steady trend upward with age. The curve for "individual contributors" – that is, not "chiefs," "supervisors" or "managers" – reaches a plateau at $12,000 at age 35, closely paralleling and about $1000 per year higher than the curve for the 1958 study of 190,000 engineers of all sorts by the Engineers' Joint Council and the 1956 survey of 108,000 by the Engineering Manpower Commission. The increase is due probably to the steady inflation of our money.

As to educational background, the A.I.M.E. figures, which include 850 Ph.D.'s (24% of the whole number responding), are more to be believed than Morrison's figures for 81 such, and show that the Doctors get about $2000 per year more than Masters and Bachelors up to age 40, but about the same salary from then on. Other interesting results are that the really large companies pay the highest salaries, on the average. About one third of the A.I.M.E.'s respondents were in the iron and steel industry (producing?) and they got higher average salaries from age 35 on than their brothers in nonferrous production and in the consumer and capital goods industries. There is little to choose between the latter two categories from the standpoint of salaries. Finally, salaries in research are lower than in either management and sales, and also seem to be stationary after age 50.

The moral of the two studies is about the same: For the most money get a good education and then be an administrator or supervisor in a large industrial unit.

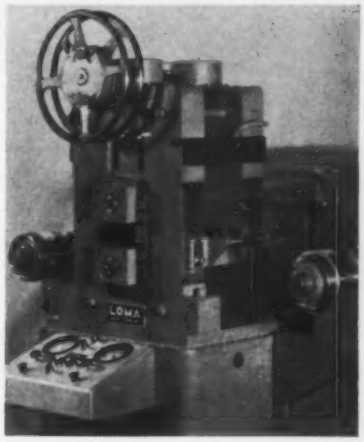
● ● ●

Speaking of a good education, there is heartening news from the Colorado School of Mines: Fall semester enrollment in metallurgical engineering showed a 19% increase, while graduate enrollment went up 13% over last year.

THE EDITORS

NEWS FROM

LOMA



This rugged and versatile reversing 2-high / 4-high combination mill brings high-precision rolling of thin-gauge ferrous and non-ferrous strip within reach of the smaller re-rolling mill, metals pilot plant and research laboratory. Occupying only 35 sq. ft. of floor space and involving a cost of less than $20,000, the machine handles up to 6 in. wide strip at rolling speeds up to 250 ft. per min. with accurate front and back tension control.

The new 8 in. mill is furnished with two sizes of 4-high work rolls, made of either alloy tool steel or solid tungsten carbide: the 1½ in. size is used for normal cold reduction down to 0.002 in. thickness, and the ¾ in. size allows special ultra-thin finishing to gauges of less than 0.001 in. In the 4-high setup, the machine handles up to ½ in. gauge; the 2-high arrangement is used for the hot or cold breakdown of heavier materials up to 1 in. thick, but is also available for skin pass rolling of thin strip.

The production of close-tolerance stock is assured by an exceptionally rugged mill design, employing steel housings of 160 sq. in. post area, super-precision needle roller journal bearings of 175,000 lb. separating force capacity, a heavy-duty mill drive with herringbone gearing and universal joint spindles, and twin-handwheel worm drive screwdowns. The machine is powered by a four-speed reversing drive offering constant horsepower from 40 to 250 ft. per min. rolling speed.

The outstanding feature of the new machine is its reversing strip coiling attachment allowing the two-way rolling of strip under tension control with no more effort than a mere flick of a selector switch. Mounted on brackets at either side of the mill, the two coiling shafts carry 8 in. diameter reels designed for a coil buildup of 6 in. Both shafts are driven from the pinion stand and are provided with dual air-operated slip clutches and brakes of ultra-sensitive, low-inertia design. Selective operation through solenoid valves and pressure regulators precisely controls the front and back tensions desired for any given mill pass.

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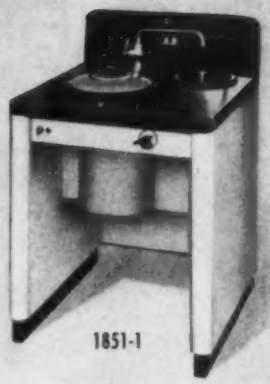

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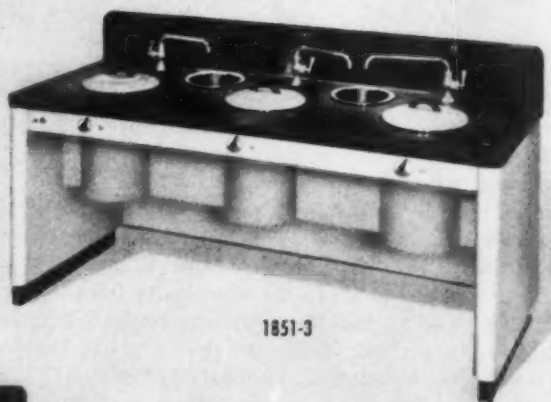

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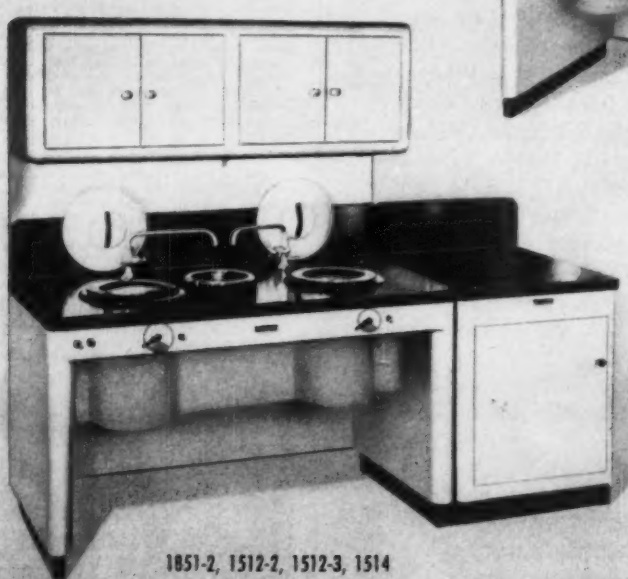

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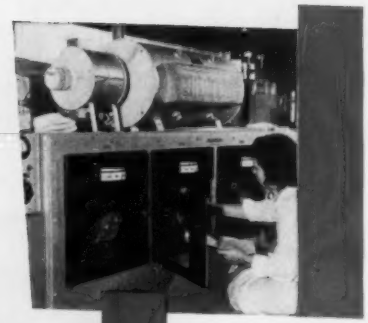

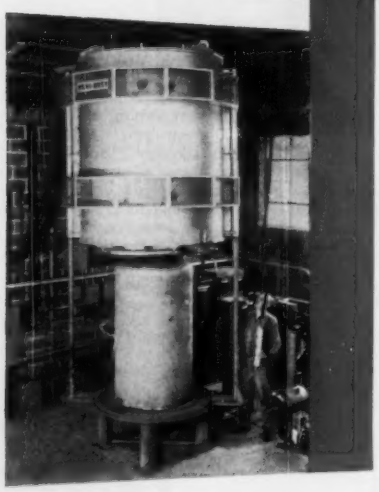

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Circle 2100 on Page 48-B

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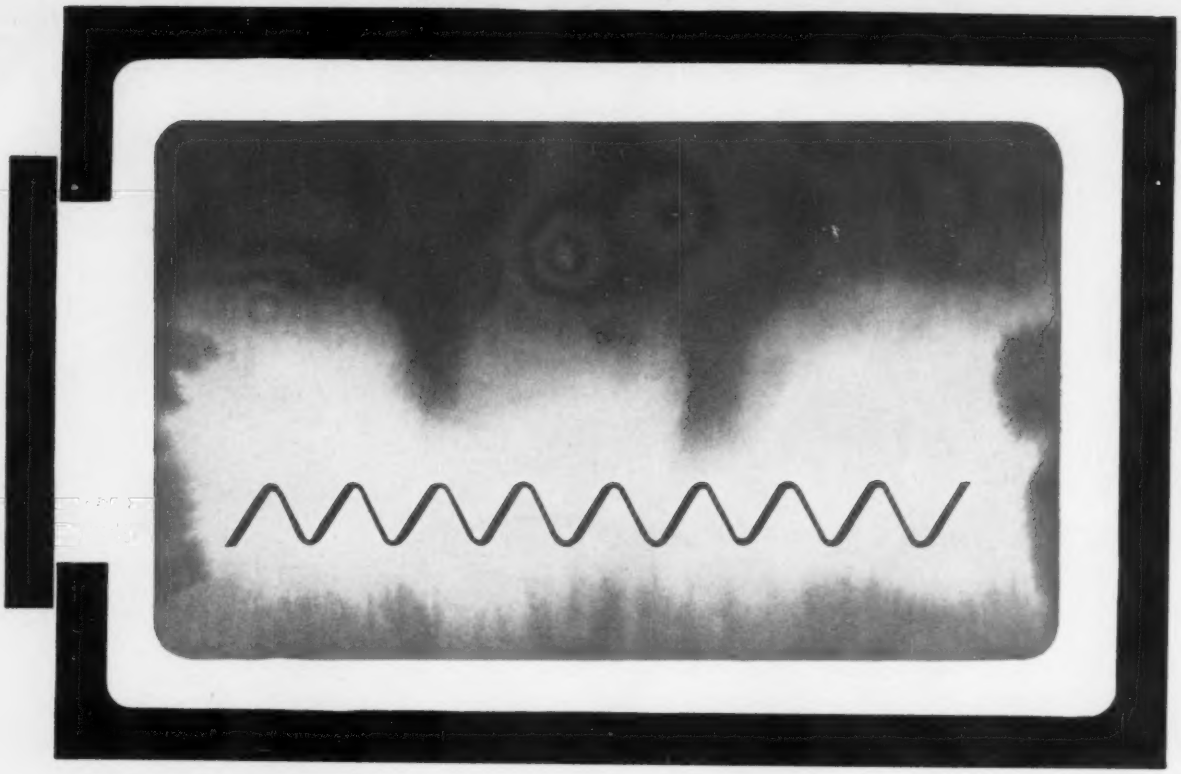
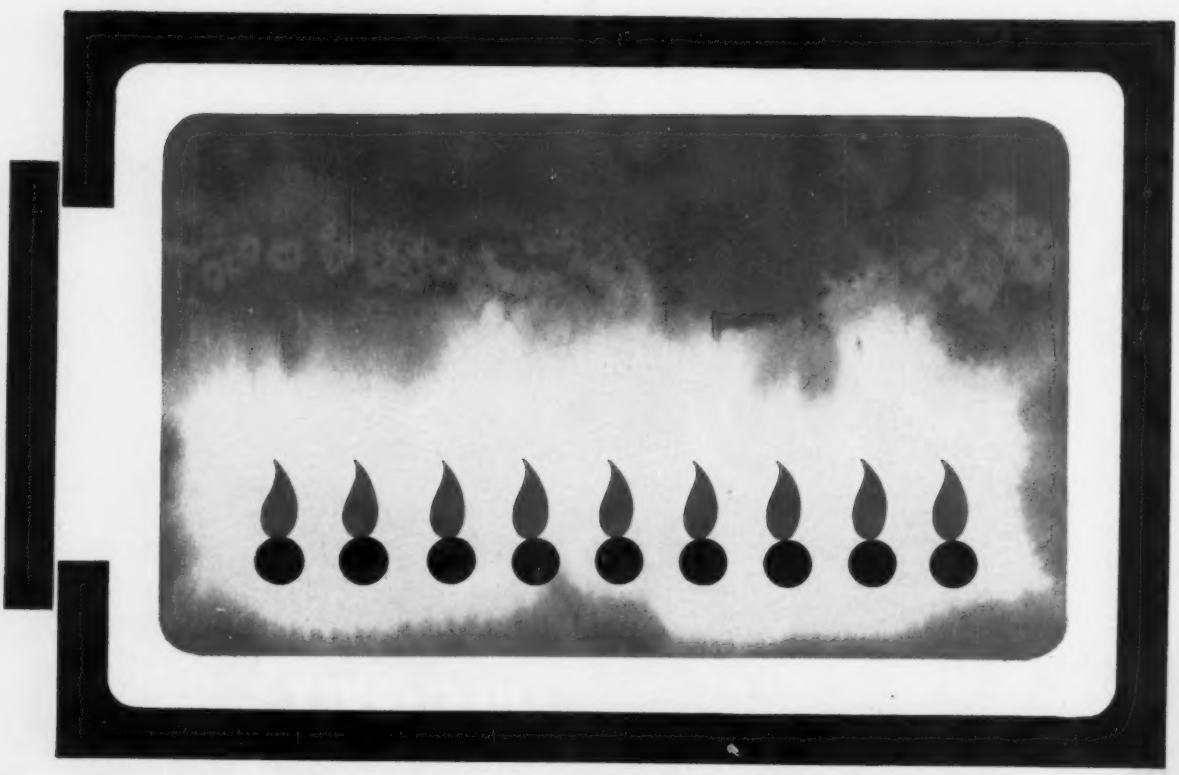


Honeywell can put your



If you're planning to put a new electric or fuel-fired furnace on the line, a Honeywell control package will save you installation time and assure you of the best possible results.
(*The package consists of a complete furnace control system and all the application engineering, installation and maintenance assistance you require.*)

Honeywell makes *all* types of furnace controls, including complete saturable reactor systems, master-slave program systems and flame safeguards.

new furnace to work faster, better

Control panels and cubicles are custom-engineered, and arrive at your plant already piped and wired. Honeywell will do the whole installation or provide standby supervision, as you prefer.

After your furnace is on the line, you can rely on Honeywell for periodic maintenance to keep your controls in top condition, and for immediate service in case of emergency.
Get complete details from your nearby Honeywell field engineer. Call him today . . .
he's as near as your phone.

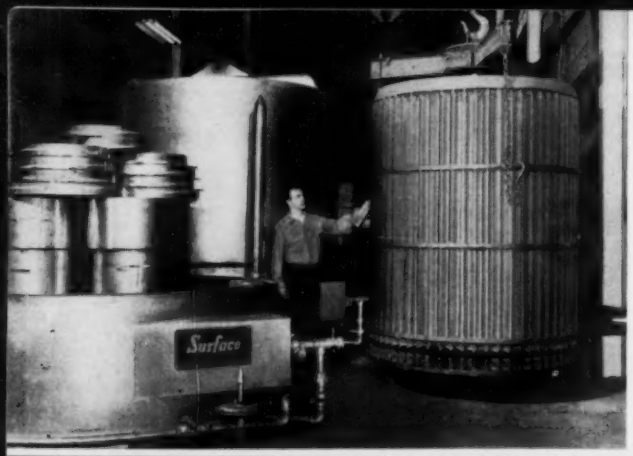
75th YEAR — PIONEERING THE FUTURE

Honeywell

First in Control — SINCE 1885

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.
In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Circle 2101 on Page 48-E

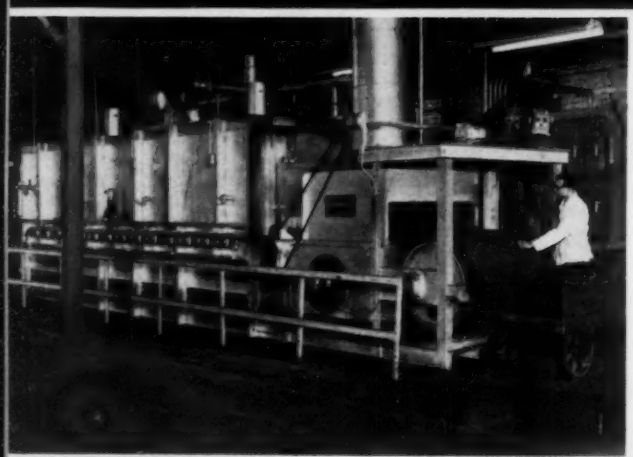


Cupro-nickel coils

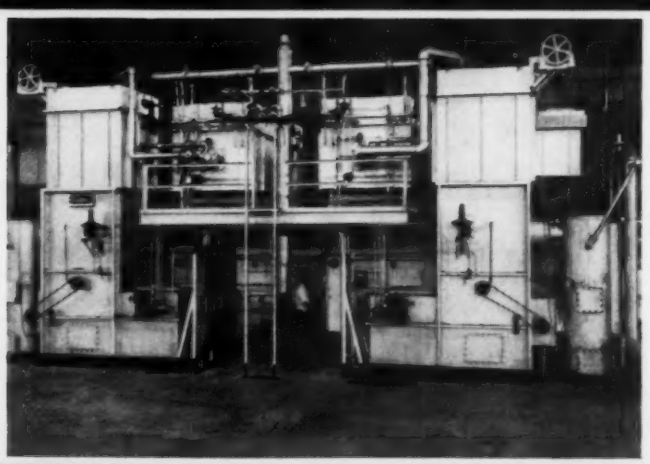
Aluminum coils

Steel gears and pinions

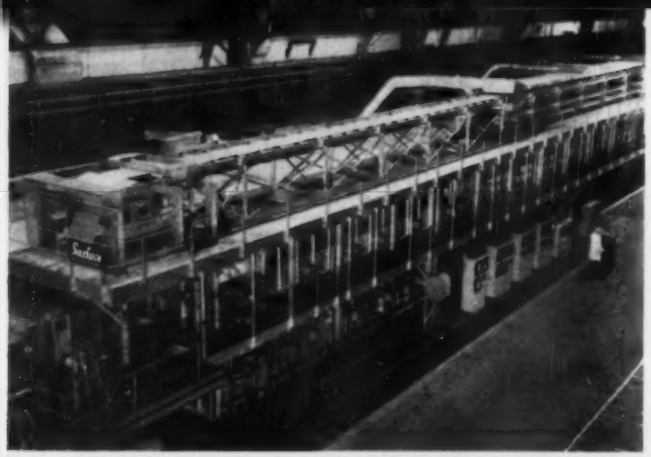
Aluminum billets



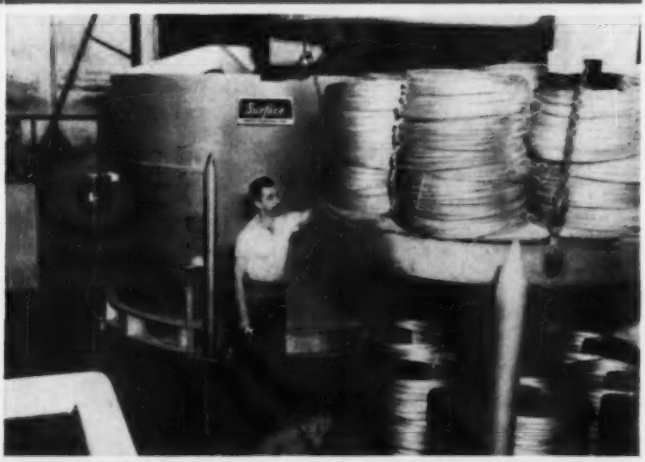
Automotive steel forgings



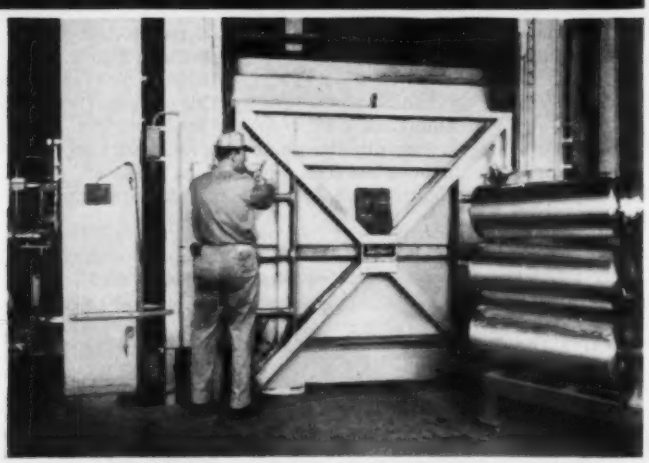
Brass tubing



Steel strip



Brass wire



Aluminum foil

How Surface Power Convection* Equipment increases speed and uniformity of heat treatment

Rates of heat transfer by radiation are limited by maximum available "thermal heads," various shapes and heat absorption properties of work pieces, and control problems which become critical when rate of heat transfer is very high.

On the other hand, heat transfer by convection can take place at rates of extreme speed, with air temperature very close to the desired work piece temperature, assuming very high air velocities.

To get such high air speeds in the first place (with fans running close to the strength and temperature limits of the best alloys available) and then use the heated air effectively in heat treating are two major problems which Surface began to tackle years ago. Gradually Surface furnaces were designed more and more like wind tunnels.

So effective are Surface's new techniques in convective heat transfer, that we can now define a furnace in terms of its **convection power:** its ability to heat the work primarily by convection, with great speed, uniformity, and efficiency.

Some of the results are spectacular; all have brought about important cost savings or product improvement. We invite you to write for Bulletin SC-182 describing Surface Power Convection equipment in more detail. Surface Combustion, 2377 Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ont.

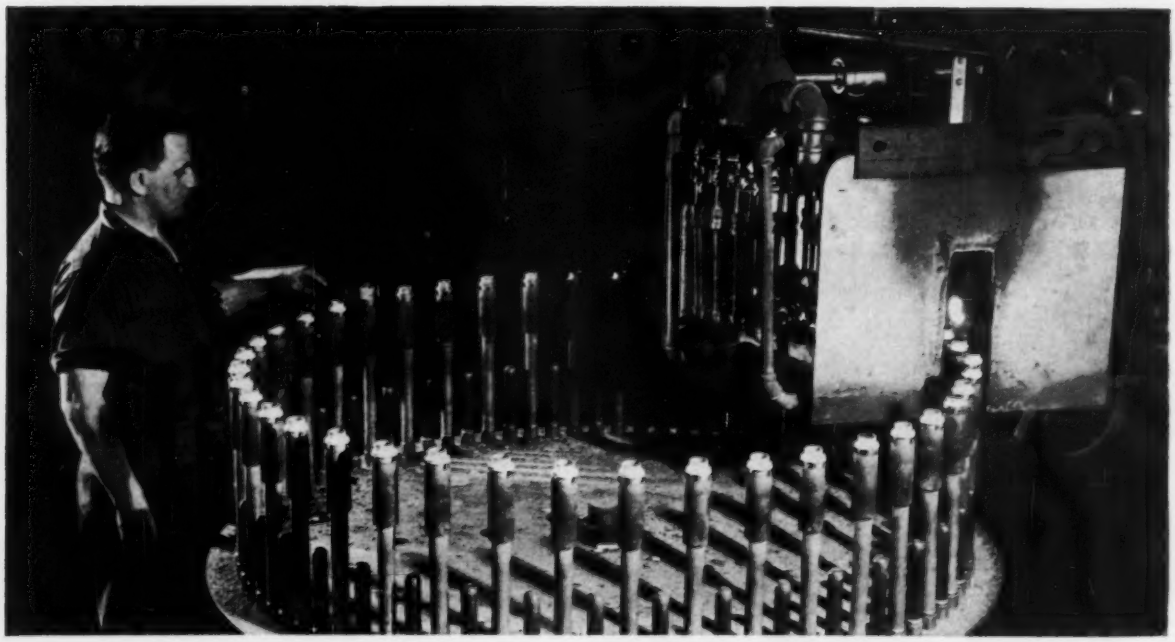
*Trademark of Surface Combustion, Division of Midland-Ross Corp.

A division of Midland-Ross Corporation MR

Surface

Circle 2102 on Page 48-8

Every Hour M. S. Little Brass Goods Company Makes 650 Appliance Fittings Better With **HANDY & HARMAN SILVER BRAZING**



Rotating jig showing mounted assemblies entering and leaving gas-air furnace.

Left– brazed assembly. Right– components with preform ring of EASY-FLO *45.*

This Hartford, Connecticut, company makes—in volume—an assembly that goes into the overflow system of household appliances. The assembly consists of brass tubing and a machined brass casting. The two components are joined by a preplaced ring of Handy & Harman EASY-FLO 45 silver brazing alloy and HANDY FLUX. Heating is automatic gas-air; parts are placed on a rotating turntable to pass through the gas furnace. Every 60 working minutes, 650 assemblies are completed.

The advantages here are that the manufacturer can use thin-walled tubing with heavier, threaded components at no sacrifice in strength. Because of EASY-FLO's penetrating qualities, the entire shear area is fully as strong as the solid parts of the assembly, yet considerably lighter. And, casting and machining the components for this assembly have been greatly simplified.

Are you in pursuit of a metal-joining method which offers—among other advantages—high, uninterrupted production at low capital investment? You may easily find the answer in Handy & Harman silver brazing. Hundreds of manufacturers and fabricators of as many different products, parts and components are right now enjoying the speed, economy, strength and *flawlessness* of brazing. You can too. Just ask Handy & Harman, 82 Fulton Street, New York 38, N. Y.

COMING IN NOVEMBER!

New Handy & Harman Brazing Correspondence Course. Simple self-study data on all phases of brazing. Send for details to Dept. BC.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

Your No. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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San Francisco, Calif.
Montreal, Canada
Toronto, Canada

Circle 2103 on Page 48-B

ANNOUNCING A NEW VANADIUM-ALLOYS DEPARTMENT FOR TOOL AND SPECIAL STEELS IN

cast to shape FORM

A brand new, completely equipped department for Cast-to-Shape tool and special steels—conventional sand casting or precision casting by the Shaw Process or shell molding—varied melting furnace capacity of 30 pounds, 300 pounds, 1000 pounds and 2000 pounds for flexibility in the casting of special analyses with maximum economy and service to our customers.

STANDARD GRADES	FORMEX—a 5% chrome hot work die steel. AIREX—a 5% chrome cold work, air hardening die steel. CROMEX—a 12% chrome cold work die steel.
SPECIAL COMPOSITIONS	Available to customer specifications.
TYPICAL APPLICATIONS	Forming rolls, cams, drop forge trimming dies, forming or blanking dies, molds, draw rings.

For sound castings of closely controlled chemical analysis, and to insure uniformity in machining and heat treating, come to VANADIUM-ALLOYS STEEL COMPANY.

50th Anniversary

FIRST QUALITY · TOOL & SPECIAL STEELS · V·A

1910-1960

VANADIUM-ALLOYS STEEL COMPANY

GENERAL OFFICES: LATROBE, PA.

DIVISIONS: Anchor Drawn Steel Co. • Colonial Steel Co. • Metal Forming Corporation • Pittsburgh Tool Steel Wire Co. • Vanadium-Alloys Steel Co.

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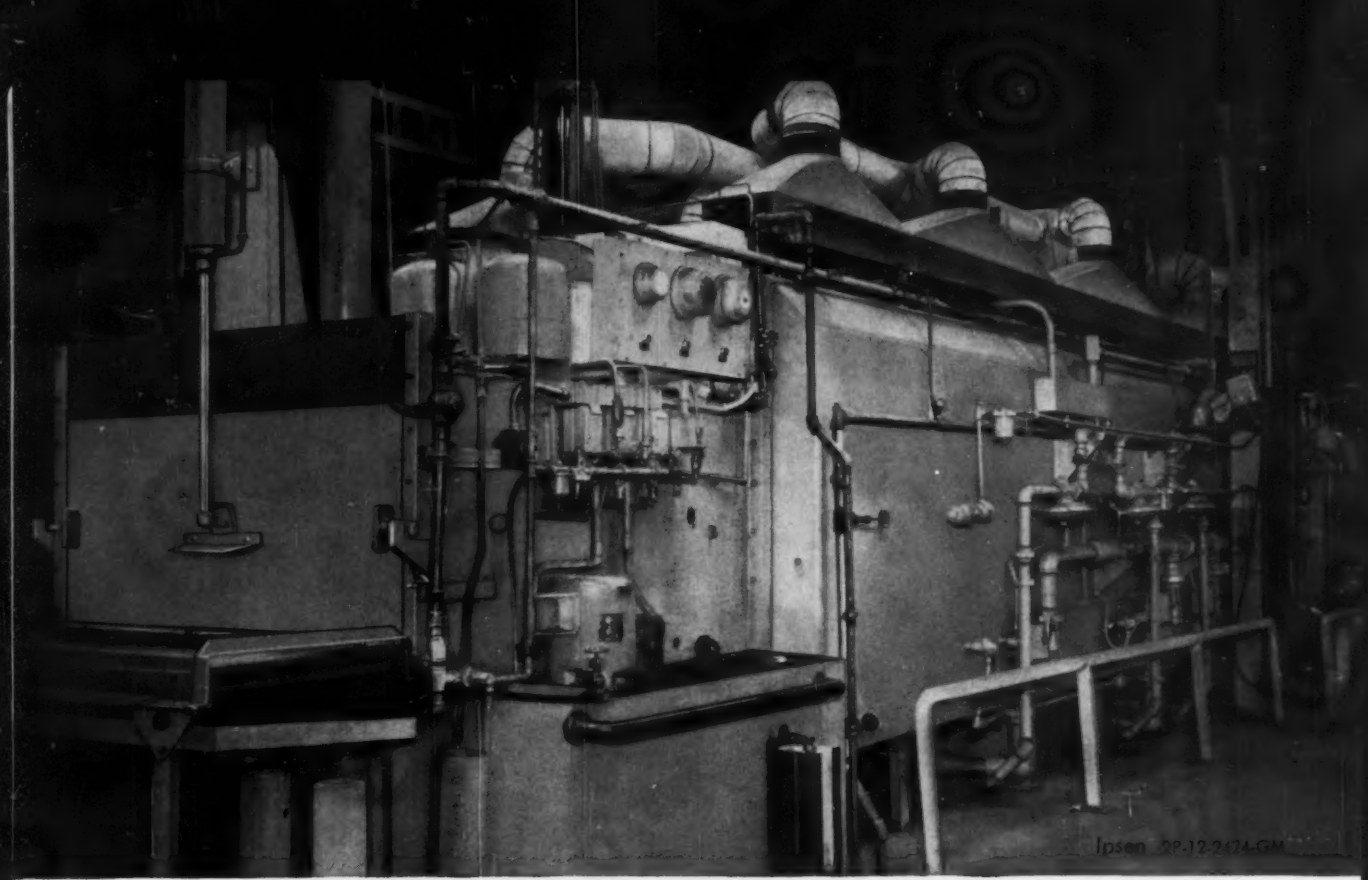
Circle 2104 on Page 48-B



Production Carburizing

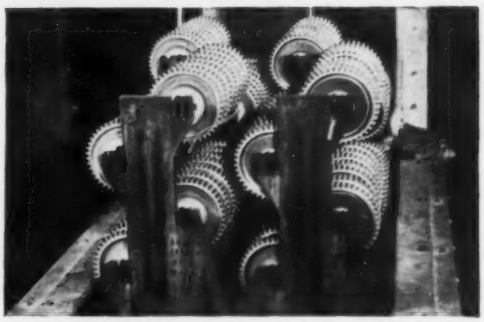
Five years ago the first Ipsen Double Row 4-Zone Pusher was built.. see photo above. It is now six years since the first Deep Case Carburizing Unit was built. BIG Ipsen controlled atmosphere pushers have given unexcelled metallurgical results!

Check these features when you consider a carburizing furnace. They are exclusive with Ipsen.

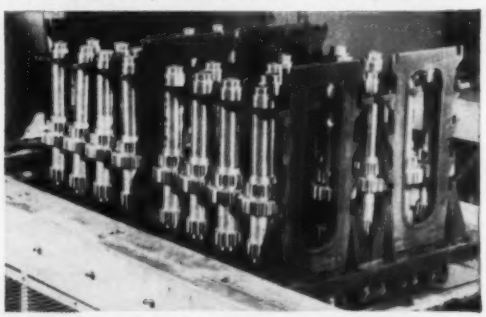
- Enclosed Charging Mechanism (Pat. No. 2,896,775)
- Chain Discharging Mechanism (Pat. No. 2,842,349)
- Baffles for 100% Forced Convection Heating (Pat. No. 2,788,205)
- Ceramic Heating Tube Mounting (Pat. No. 2,822,798)
- Ceramic "Flame-Busters" (Pat. No. 2,861,596)
- Ceramic Fan (Pat. No. 2,730,352)
- Water-Cooled Fan Motor (Pat. No. 2,800,317)
- Quench Oil Flow System (Pat. No. 2,854,013)

Other Patents Pending

Ipsen Pusher furnaces are described in Bulletin P-59. Send for your copy today.



This charge of steel gears is typical of work handled in Ipsen Production Carburizing Furnaces. Heating was 1700° F for 10 hours; oil quenched at 150° F. Case depth: .045".



Countershafts ready for charging into Ipsen Production Carburizing Furnace. Heating time was 10 hours at 1700° F; quenching was in oil at 150° F. Case depth: .045".

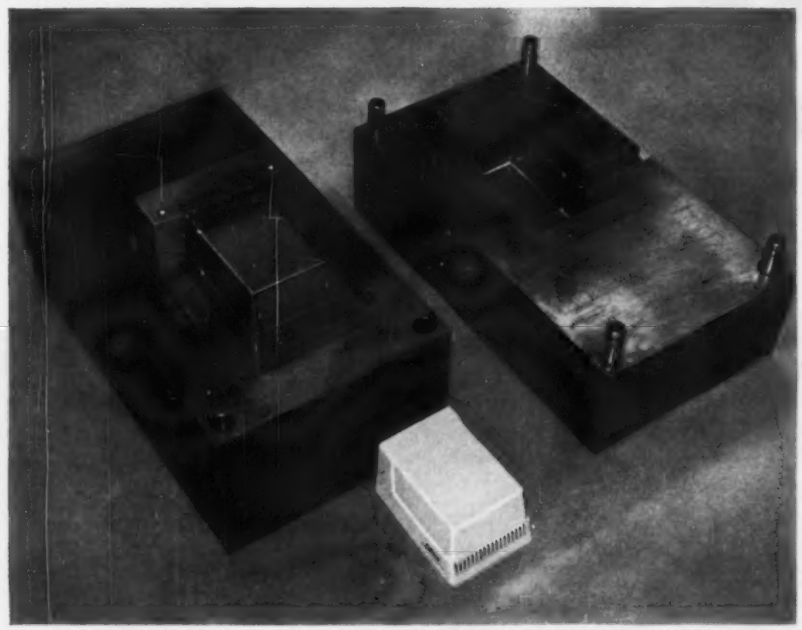
AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • DEPT. 23 • P.O. BOX 500 • ROCKFORD, ILLINOIS

Circle 2105 on Page 48-B

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.



LUSTRE-DIE does smooth job in molding can-opener housing

Bethlehem Lustre-Die tool steel, which is furnished pre-heat-treated in bars, recently turned out a top-quality molding of high-impact polystyrene at Cepco Plastics Co., St. Louis. The plastic-injection mold, made by Lambert Engineering Co., produced a sturdy, attractive can-opener housing for Swing-A-Way Manufacturing Company.

Here are the reasons why Lustre-Die made such a hit: 1. It saved time, because no heat-treatment was required. 2. It was easier to machine than other pre-hardened grades which were previously used. 3. It polished beautifully, and imparted a high sheen to the finished part.

An electric-furnace steel with a well-balanced basic analysis, Lustre-Die is ideal for working with plastic because it takes a glossy polish. This tool steel also has something extra: a special alloy fortification which further increases its depth of hardenability and enhances its mechanical properties. It is heat-treated by oil-quenching and tempering at the mill, and is furnished ready for machining and polishing. Careful manufacture and quality control insure its freedom from porosity.

You can take our word for it—Lustre-Die is just what you need for a good plastic-molding job. For full details, and prompt delivery, get in touch with your Bethlehem tool steel distributor.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Straighten tools while they are hot

Though seldom recognized or appreciated, straightening is an essential part of the quench and temper hardening operation on long, slender tools. The correction of warpage which occurs either in heating tools to the quenching temperature, or from stresses generated in the quench, must be done during heat-treatment. Only minor straightening can be done on hardened tools at room temperature after the hardening operation is complete.

For example, the major straightening on a long rectangular shear blade must be done during quenching. The heat-treater learns by experience at what point the quench can be interrupted so that straightening can be performed. This point varies with the grade of tool steel, and the size and shape of the shear blade. Straightening usually is performed by bending the tool slightly on a press (so-called gag straightening).

Small amounts of additional straightening can be accomplished when the tool is at the tempering temperature. Or, if necessary, this can be done by reheating to a point just below the final tempering temperature.

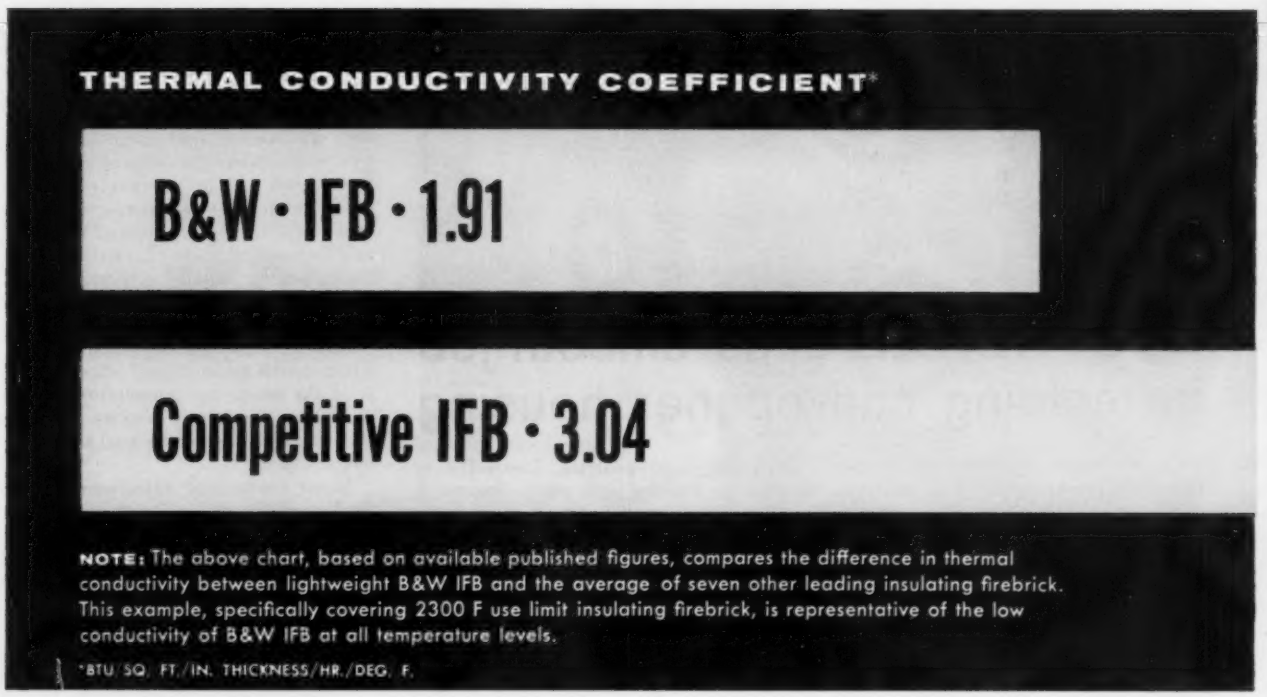
Minor mechanical adjustments in the final assembly of tools and components are often made by peening the concave surfaces with a hand hammer. This should be done cautiously to avoid spalling or cracking. However, it is preferable to straightening by cold-bending.

New Booklet on Oil- and Air-Hardening Grades

We have a new illustrated booklet on oil- and air-hardening tool steels. It presents essential data about the BTR, Air-4, Lehigh H, and A-H5 grades. For your copy, write to Publications Dept., Bethlehem Steel Co., Bethlehem, Pa. Ask for Booklet No. 532.

Another *plus* of Lightweight B&W Insulating Firebrick

LOWER THERMAL CONDUCTIVITY means


THERMAL CONDUCTIVITY COEFFICIENT*
B&W · IFB · 1.91
Competitive IFB · 3.04
NOTE: The above chart, based on available published figures, compares the difference in thermal conductivity between lightweight B&W IFB and the average of seven other leading insulating firebrick. This example, specifically covering 2300 F use limit insulating firebrick, is representative of the low conductivity of B&W IFB at all temperature levels.
*BTU/SQ. FT./IN. THICKNESS/HR./DEG. F.

All insulating firebrick are not the same. Published figures show wide variations in *all* of the important properties among the leading brands of IFB.

Take thermal conductivity. This important property affects fuel costs, temperature control and the speed with which a furnace heats and cools. Thermal conductivities range from a B&W low of 1.91 to a high of 3.47 for a competitive IFB—*almost a 100% difference in wasted heat and fuel costs.*

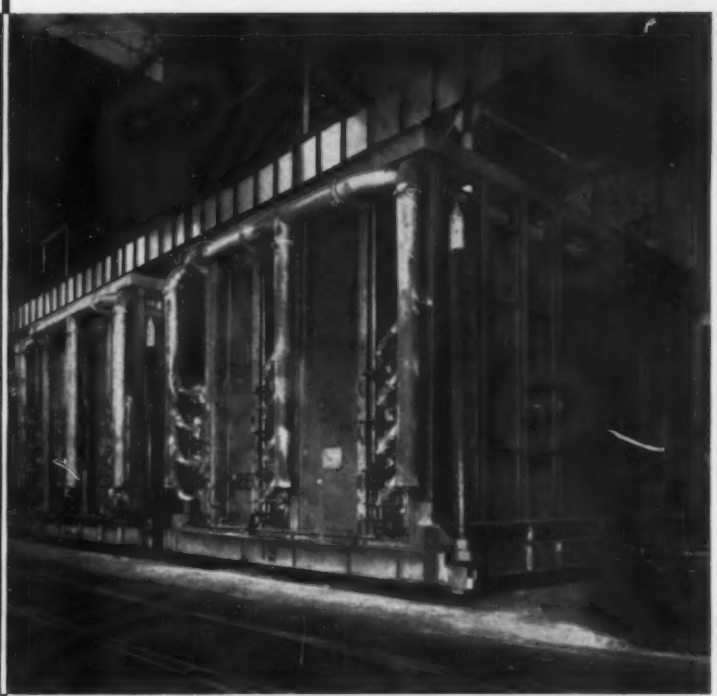
You are paying for insulating firebrick . . . make sure you get *all* the benefits. B&W—the originator of IFB—manufactures a full line of IFB with an experience-proved balance of light weight, high insulating value, high strength and long life.

For complete information on B&W Insulating Firebrick, write for Catalog R-2-H to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

NUMBER 1 OF A SERIES

LOWER FUEL COSTS

the payoff



- **14% lower fuel costs • 30 F lower casing temperature**
- **25% less time to reach operating temperature • 12 hours saved per cycle**

These are the results of a direct comparison of two furnaces of the type shown above, one lined with B&W IFB and the other with one of the better competitive insulating firebrick. That's how B&W pays off for a major steel company in their 8-stack, hood type, strip annealing furnaces. This is just one of many proofs in our files that "there is an important difference in insulating firebrick."

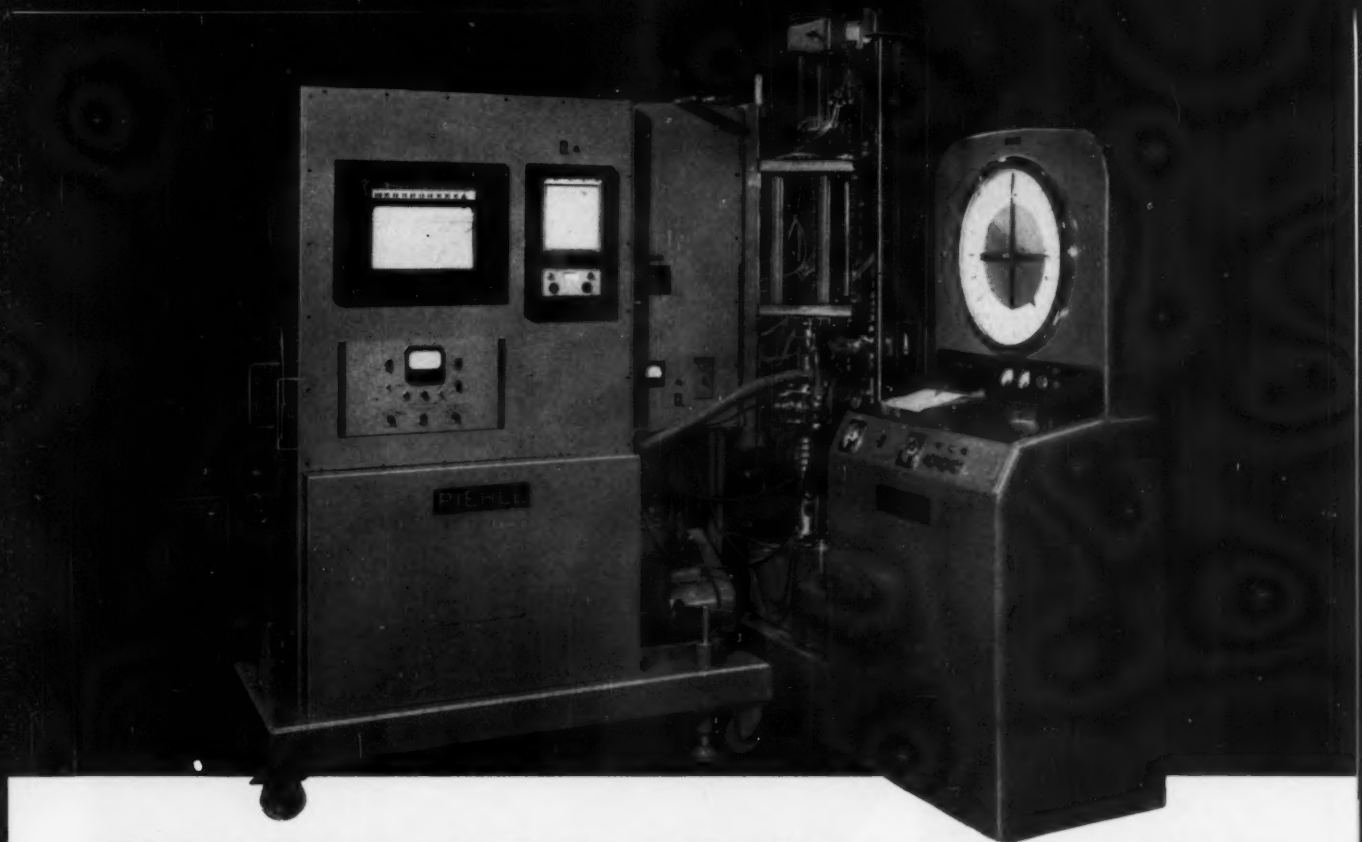
R-659

B&W

THE BABCOCK & WILCOX COMPANY

REFRACTORIES DIVISION

Circle 2055 on Page 48-B



Riehle Universal Testing Machines assure maximum versatility for research and control practices

To facilitate modern research and control testing, RIEHLE offers both Screw Power and Hydraulic Testing Machines in capacities from 2000 lbs. to 450,000 lbs. These sensitive and rapid response machines are available with complete instrumentation and accessories including a high temperature vacuum furnace capable of testing materials up to 4000° F.

A full range of holders and specimen tools, automatic strain rate and load rate controls and load cells to extend lower ranges accurately are available. With instrumentation, RIEHLE Testing Machines can be adapted for metals, ceramics, plastics, glass, timber and textiles for virtually any physical test measured in units of load and specimen deformation.

Recommendations for testing procedures and equipment to meet specific requirements will be furnished by RIEHLE engineers on request. Also send now for illustrated catalogs describing RIEHLE Hydraulic and Screw Power Universal Testing Machines and complete Recorders and Accessories.

OTHER RIEHLE TESTING MACHINES include Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers and Portable Hardness Testers for Rockwell Readings.

RIEHLE TESTING MACHINES
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Please send free literature on RIEHLE Testing Machines.

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Circle 2056 on Page 48-B

Riehle® TESTING MACHINES

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"One test is worth a thousand expert opinions"

Divisions of American Machine and Metals, Inc., New York 7, New York

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NEW PRODUCTS

Heat Resistant Materials

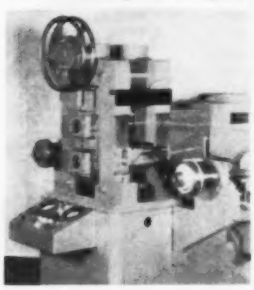
Ceramic Insulators

In many processes involving heat transfer, the tube edges in heat exchangers often deteriorate due to the abrasive or corrosive action of gases or liquids. Special ceramic ferrules fitted into the ends of the tubes or flues can withstand temperatures up to 2400° F. and are abrasion and acid resistant. The ferrules come in lengths up to 12 in. and in I.D.'s from ¼ in. to 2 in. *Saxonburg Ceramics.*

For further information circle No. 1760 on literature request card, p. 48B

Cutting and Forming Equipment

Narrow-Strip Rolling Mill



The "Model 600" 2-high/4-high combination mill will precision-roll ferrous and non-ferrous strip down to 0.001 in. thick. The equipment will handle up to 6-in. wide strip at rolling speeds up to 250 ft. per min. A feature of the machine is its reversing strip coiling attachment which allows the two-way rolling of strip under tension control. A change in work rolls can be made by one operator in 10 min.; a complete 2-high/4-high changeover requires 30 min. *Loma Machine Manufacturing Co., Inc.*

For further information circle No. 1761 on literature request card, p. 48B

Ultrasonic Impact Grinder

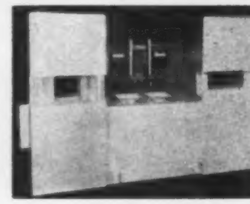
The "Model 2-333" will precision machine an area up to 1⅜-in. in diameter on semiconductor materials. It can also be used for general purpose work including cleaning and soldering. The machine features an air-cooled, 300-watt magnetostrictive transducer which provides continuous operation and eliminates down-time for cooling. *Raytheon Co.*

For further information circle No. 1762

Industrial Heating Equipment

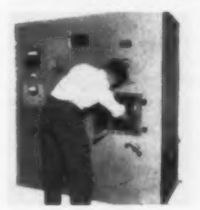
Toolsteel Treating Furnace

A complete heat treating plant in one compact unit is being offered by the *Waltz Furnace Co.* It consists of a heating furnace (12 by 10 by 18 in. deep) with a range of 1000 to 2400° F., a recirculating-type tempering oven (21 by 10 by 10 in. deep) with a range of 250 to 1100° F., and two quench tanks (oil and water). A foot-valve controls the opening and closing of the furnace doors. The unit, available in either electric or gas-fired models, can treat all types of water and oil hardening steels.



For further information circle No. 1763 on literature request card, p. 48B

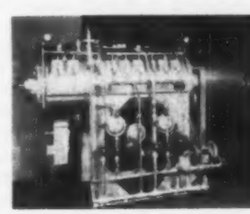
Console Vacuum Furnace



C. I. Hayes, Inc. is introducing a compact 30 kva. vacuum furnace unit, "Model VAC-52", with a maximum furnace temperature of 2200° F. and vacuum capability in the 10^{-4} mm. Hg range. Installation consists of simple connections to water and power. Interchangeable heating elements and radiation shields allow temperatures to 3000° F. and increase operating flexibility for vacuum brazing and heat treating operations.

For further information circle No. 1764 on literature request card, p. 48B

Continuous Rotary Furnace



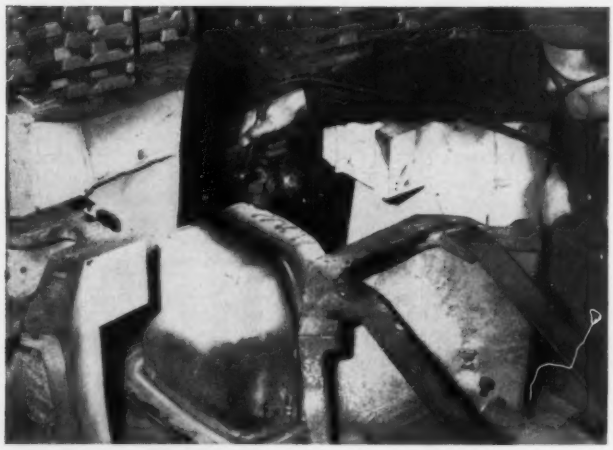
An "Automotion" furnace, exhibited at the Metal Show, keeps parts in motion during heating and quenching, thus assuring uniformity in processing. This feature plus atmosphere control and automatic feeding is particularly advantageous in carburizing and case hardening because it eliminates "point-of-contact" case variation. The "Model 136-MGE" rotary-type furnace, with a built-in continuous feeder, can process up to 250 lb. per hr. *American Gas Furnace Co.*

For further information circle No. 1765

Temperature Test Chamber

A "Hi-Lo" test chamber has a rapid cycling chamber for shock testing metal parts; it permits temperature drops to −100° F. in seconds. Automatic cycling of high and low temperature levels for varied time periods is possible. The range is −100° F. to +400° F., controlled

AQUADAG® SOLVES AN INTRICATE MOLD PROBLEM FOR OSWEGO CASTINGS



A complete permanent mold, used in casting high-pressure gas meter housings, is shown being sprayed with 'Aquadag'.

The problem at Oswego Castings Corporation, Oswego, New York, a division of Oberdorfer Foundries, Incorporated, involved the effective metal flow and release of aluminum castings. Frequent breakage occurred due to the complexity of the part . . . a gas meter housing containing an integral rib down the center. In the mold core, the relatively tiny aperture for forming the rib, plus the rounded corners which provide the outer "bucket" appearance to the housing, demanded a release agent that would permit easy extraction and proper metal flow.

According to Frank Fox, Production Foreman in the Oswego foundry, previous to adopting the use of an Acheson dispersion, removing the aluminum casting from the rib aperture took as long as three or four hours. Even with such care, sticking caused many castings to break at the point of the rib.

There was also the problem of metal flow. Housing walls vary in thickness between ¼ inch and the ⅝ inch flange which runs around the top. Close tolerances must be maintained to insure a proper fit during final assembly. "Holidays" caused by the improper flow of metal into critical areas of the cavity, presented a constant reject problem.

Several mold washes were tried unsuccessfully before Oswego engineers turned to 'Aquadag'—a dispersion of colloidal graphite in water. In their application, Oswego dilutes the concentrated material 1 to 3 with water. Normal commercial spray equipment is used in applying an even coating on all mold surfaces . . . one coating holding up through a run of eight to ten pieces. The 356 aluminum alloy used for the housing castings, is poured at 1400°F. The mold is preheated to 700°F. and maintained at that temperature through the casting cycle.

With 'Aquadag', the savings at Oswego have been "considerable". Castings are more uniformly formed, have smoother surface finish, and part easily. Because of greatly facilitated metal flow and release, mold life is lengthened. Rejects are the exception rather than the rule.

Oswego Castings manufactures several products with highly defined parts which require molds having intricate sliding members or collapsible cores. The fact that finding the effective lubricant they needed to overcome their *most difficult* problem, resulted in the selection of an Acheson product . . . indicates it can be of equal value to you. We invite your inquiry.

Literature Describes Production Economies In Metal Casting

A detailed discussion of the various Acheson semi-colloidal and colloidal dispersions available for coating permanent molds, die cavities, and steel and cast-iron chills, is contained in Acheson Bulletin 425. It describes why Acheson colloidal graphite is so extensively used as a mold and die lubricant, as well as an extremely effective heat-resistant parting agent. The microscopically fine graphite particles are suspended in a variety of liquid carriers. When mixed with the appropriate diluent, the dispersion can be conveniently applied by spraying, brushing, dipping, or swabbing. As mold coatings they provide greater, more uniform surface coverage. Highly tenacious, these thin coatings resist the scouring action of molten metal, do not volatilize, and will not build up. Sticking in the mold is reduced to a minimum; usually eliminated completely. Less finishing is required, rejects are fewer, and die and mold life is extended.

Additional protection of casting machines, conveyor chains, and other plant equipment is also described in Bulletin 425. The heat-resistant, non-gumming characteristics of Acheson colloidal graphite are ideally suited for the high operating temperatures of most foundry machinery. Should yours be a special lubricating problem not covered in this literature, let us hear from you. Industry experience has been that in our complete product line there is an Acheson dispersion "tailor-made" for your metal casting application.

We invite you to send for your copy of Bulletin 425, "Colloidal Dispersions For Use In Metal Casting", at your earliest convenience. It should prove helpful to you in realizing greater production economies. Write direct to Dept. MP-110.

'dag', 'Aquadag' are trademarks registered in the U.S. Patent Office by Acheson Industries, Inc.

A C H E S O N

dispersions digest reporting uses for

dag® BRAND DISPERSIONS

ACHESON

ACHESON *Colloids Company* **PORT HURON, MICHIGAN**

A division of Acheson Industries, Inc. Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Offices in:

Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • New York • Philadelphia • Pittsburgh • Rochester • St. Louis

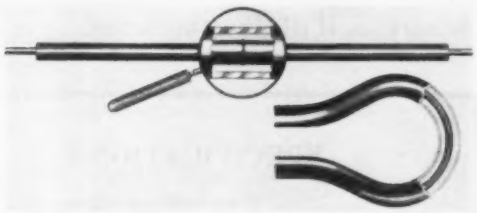
Circle 2057 on Page 48-B

within ±1° F. The coolant is liquid CO_2 dispersed by a high-velocity blower. Optional features include a percentage timer, an observation porthole, and provision for an external vibrator. *Electric Hotpack Co., Inc.*

For further information circle No. 1766 on literature request card, p. 48B

Single-Wire Hot-Junction Thermocouple

Where extreme temperatures and pressures, corrosive conditions, or mechanical stresses are encountered, "Con-O-Clad" thermocouples with unbroken mineral oxide insulation and continuous metal sheath provide rugged construction and longer life. A faster response is obtained



since the uniform diameter of the hot junction has less mass than other types. *Conax Corp.* offers the thermocouple in 1/16 and ⅛ in. diameters and a choice of almost any metal for sheathing. High-temperature, high-pressure fittings are also available.

For further information circle No. 1767 on literature request card, p. 48B

Low-Temperature Infrared Burner Unit

A burner with "controlled wavelength" radiant emission for efficient heat transfer has been designed specifically for low-temperature processing applications. Every material has a maximum heat absorption wavelength. Most are concentrated in the range at which this gas

burner unit emits radiant heat—thus providing optimum heat transfer efficiency. The face temperature of the 4 by 18 in. Inconel screen can be adjusted from 1200 to 1800° F.; heat output per unit is 30,000 Btu. per hr. Applications include curing shell molds and foundry cores. *Bryant Industrial Products.*

Circle No. 1768 on card

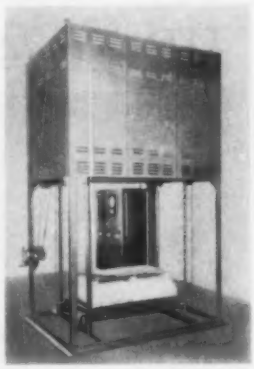
Recirculating Furnace

Sunbeam Equipment Corp. is introducing a pit furnace for annealing, tempering, and stress relieving ferrous and nonferrous alloys in the range 300 to 1400° F. A high-volume fan assures rapid and uniform heating. Gas-fired or electrically heated, seven models have chambers ranging in size from 18 in. diameter by 36 in. deep to 36 in. diameter by 36 in. deep.

For further information circle No. 1769 on literature request card, p. 48B

Elevator Furnace

The "Model NMR-24E" elevator furnace will maintain a temperature up to 2700° F. within ±5° F. for firing electronic or other ceramic parts in air or an inert atmosphere. Muffles can be supplied for brazing and other lower-temperature processing. Close temperature differentials can be maintained between the top and bottom of the furnace chamber. *Harrop Precision Furnace Co.*

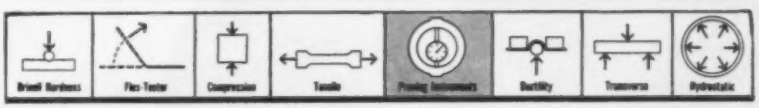


Circle No. 1770 on card

Laboratory Oven

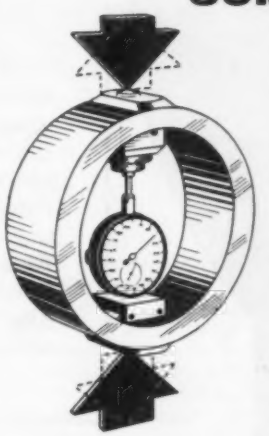
A laboratory oven for temperatures to 1000° F. provides automatic heat control within ±½° F. and can be adapted for sintering, aluminum treating, or glass annealing. Six models range in size from 13 by 13 by 13 in. to 48 by 30 by 42 in. Gas-fired models feature controlled combustion with atmospheric burners; electric units use vertical heating elements of open-coil design. *Despatch Oven Co.*

For further information circle No. 1771 on literature request card, p. 48B



proving rings to measure any load

COMPRESSION or TENSION



Steel City offers two styles of proving rings which require no adjustment during use. The dial-indicator ring (illustrated) measures deflection in increments of 0.0001". Applied load or force is determined from a calibration report furnished with each instrument*. With this type of ring, even an inexperienced operator can repeat readings as close as 1/10 of 1%.

Optical-type proving rings, developed for the USAF, use a ruled scale and a high-powered microscope for readings in increments of 0.00002". Repeat readings as close as 1/20 of 1% can be achieved.

Compression and tension models are available in either style, with capacities up to 200,000 lb., all manufactured of special-alloy steel by experienced craftsmen. They are used for calibrating Brinell testers, testing machines and presses, and load cells, or for measuring applied loads.

* *National Bureau of Standards calibration report when desired.*

Write for literature, prices and name of nearest distributor.

Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.

Circle 2058 on Page 48-B

NEW BALTOGRAPH 300 PENETRATES UP TO 4" OF STEEL

permits 360° radiography and can be coned down to a single beam . . . yet weighs only 136 lbs.

This is the first industrial X-ray unit designed specifically to meet *all* radiographic inspection requirements, from thin aluminum up to 4" thick steel. Simple to operate . . . requiring only a few hours instruction.

For a free demonstration—at your plant or job site—just call, wire, or write to Mr. Dan Maus, X-ray Department, Westinghouse Electric Corporation, 2519 Wilkens Avenue, Baltimore 3, Md.—*You can be sure . . . if it's Westinghouse.*

J-08386

SPECIFICATIONS

X-ray Head

X-ray tube, lead shielding, HT transformer, filament heating transformer, and automatic thermal cutoff device are all mounted in a single lightweight housing.

X-ray portal: Total X-ray beam is 30° circumferential
Focus size: 2 x 2 mm
Inherent Filtration: Low
Shielding: 5 mm of lead
Power rating: Self-rectified 300 KVP-3MA
Weight: 136 lbs.
Dimensions: 46¼ long, 12¼ diameter

Control Panel

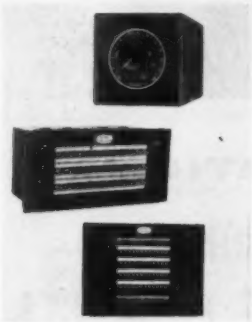
Hermetically-sealed penetration meter, penetration selector, MA control, and automatic push button reset timer mounted in rugged metal cabinet.

Power Supply: 115 or 230 volts, 60 cycles, single phase
Weight: 41 lbs.
Dimensions: 15" x 12" x 7"
Also included: 25' and 60' connecting cables and individual carrying cases.

Westinghouse

Circle 2059 on Page 48-B

Thermocouple Selector Switches



Rotary, key, and push-button selector switches for thermocouple and resistance thermometer applications provide rapid, accurate switching from 1 to 144 sensing elements. Key and push-button switches will average two temperatures, or switch a measuring instrument to different measuring points. Rotary models have capacities of 6, 12 or 24 points. False voltages from thermoelectric action are eliminated because switch contacts and wipers are of the same material. *Thermo Electric Co., Inc.*

For further information circle No. 1772 on literature request card, p. 48B

Expendable Thermocouple Cartridge

The "Temtip" cartridge for measuring steel bath temperatures has a metal cap which protects the platinum thermocouple during immersion. The cap can be easily removed for measuring nonferrous melts at lower temperatures. The cartridge and its receptacle are fully compensated to assure accuracy. No modification of a "Speedomox" temperature recorder is necessary to adapt to the Temtip cartridge. *Leeds & Northrup Co.*

For further information circle No. 1773

Cleaning and Finishing

Liquid Buffing Applicator

A "Traveling Gun Mover" is designed for use with wide buffs, where the application of a uniform spray of liquid compound is a problem. The equipment increases liquid compound adherence, which results

in cleaner, more economical buffing and polishing operations. The gun-mover mechanism permits a wide variation in width of travel and can be used with single or multiple buffing systems. *Frederic B. Stevens.*

For further information circle No. 1774 on literature request card, p. 48B

Ultrasonic Cleaner

A self-tuning ultrasonic unit from *Powertron Ultrasonic Corp.* does not require operator attention – it maintains optimum cleaning performance with a feedback transducer which automatically compensates for varying load conditions. The 1000-watt "Autosonic" unit may be combined in modular installations to give up to 10 kw. output. Cleaning tanks with capacities of 8 and 32 gal. are available in the "PT-10001" series.

For further information circle No. 1775 on literature request card, p. 48B

Electrostatic Spray Gun

A hand spray gun (demonstrated at the Metal Show) can apply conductive, water-base, or standard paints without special formulation. The portable "Model 10" atomizes particles of coating material centrifugally and then charges them electrostatically. The charged particles are guided directly to the object being coated, which results in maximum painting efficiency. *Ionic Electrostatic Corp.*

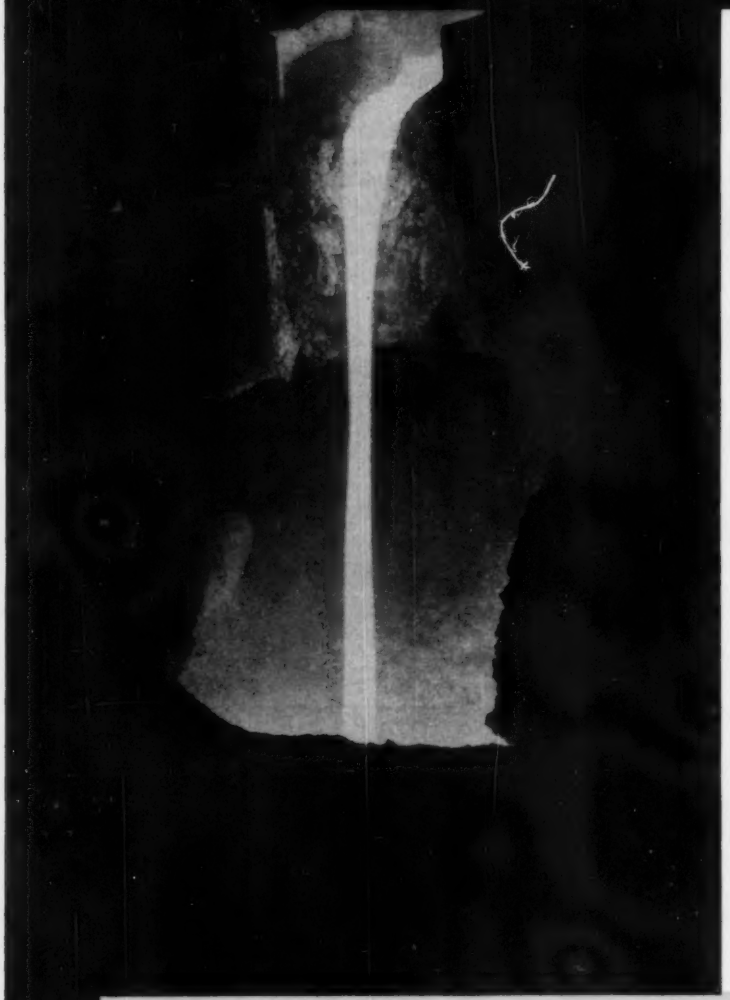
Circle No. 1776 on request card, p. 48B

Automatic Two-Color Spray Painting

Automatic spraying of two colors in the same booth, without masking, can be done with equipment manufactured by *DeVilbiss Co.* This versatile, airless gun, designed for high-speed production, will apply any

MINIMIZE BURN-OUT...
PSC's All-Sheet Construction Adds to Furnace Tube Life
Experience of users shows much lower frequency of burn-out, with tube life extended up to 100%. In PSC tubes, precision-welded bends are of same metal and thickness as the legs. The continuously smooth walls result in uniform flow of gas, and reduce the carbon build-up and bend burn-out, which commonly result from the rough interiors of cast alloy bends. Lighter than cast by 33 to 50%, PSC radiant tubes cost less initially. Any size, shape or alloy.
All Types Heat-Treat Units
PSC
THE PRESSED STEEL CO. • Wilkes-Barre, Pa.
Circle 2060 on Page 48-B

In iron foundries today the trend is to...

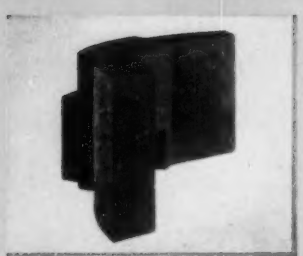


NATIONAL
TRADE MARK

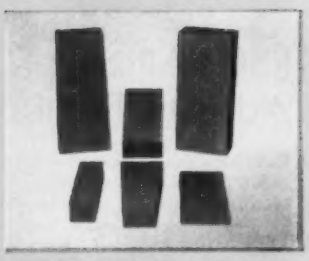
CARBON AND GRAPHITE PRODUCTS

When your operations require refractories to handle molten irons either inside or outside the cupola, you'll realize economic advantages when you use "National" carbon and graphite products. Why? Because carbon and graphite have no melting point... resist slag and thermal shock... are not wet by molten irons... have low thermal expansion... increase in strength with increase in temperature.

Whether you use carbon block and brick for lining cupolas and runout troughs... carbon paste for patching ... graphite tubes for injection and upgrading of iron... graphite plungers for producing ductile iron... or core rods and chill plates—you'll find these products all help reduce maintenance, speed production and lower overall costs. For details write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.



CARBON BLOCKS—Provide long refractory life in the cupola.



CARBON BRICK AND PASTE—Proved materials for cupolas and runout troughs.

GRAPHITE TUBES—Unsurpassed for carburizing with graphite powder and injection for upgrading.

"National" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

NATIONAL CARBON COMPANY

UNION CARBIDE

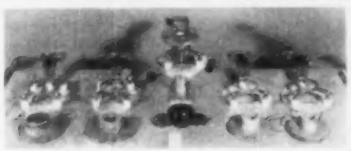
material capable of being sprayed by the airless method, including water-soluble paints. The gun is simple to operate and spray control is excellent.

For further information circle No. 1777 on literature request card, p. 48B

Welding and Joining

Multi-Purpose Brazing Fixture

The use of several sizes of interchangeable work-coils and adaptors permits the brazing of different sized brass sleeves to cold rolled steel on a single holding device. Sleeve-collar assemblies can be



brazed in one minute or less with *Induction Heating Corp.'s* "Thermomic Model 2500" generator. After the work is positioned in the unit, the balance of the brazing cycle is automatic.

For further information circle No. 1778 on literature request card, p. 48B

Manual Metal-Arc Welder

The *Air Reduction Sales Co.* announces a manual gas-shielded metal-arc welding gun and controls, designed for both light and heavy fabrication where short welds, off-the-ground welding, or emergency repairs are required. The "MIGet"

gun carries its own compact reel of wire, drive rolls and speed controls. It is rated at 200 amp. (d-c. reverse polarity) using argon or helium, and 300 amp. (d-c. reverse polarity) using CO_2. The gun will handle aluminum wire from 0.030 to 0.062 in. in diameter.

For further information circle No. 1779 on literature request card, p. 48B

Here's where metals, semi-conductors and other solids are ionized for analysis by the solids model of CEC's new 21-110 Series Mass Spectrometer.

First to provide ultra-high resolution and versatility for advanced materials research of solids, liquids, and gases, the 21-110 distinguishes mass differences beyond the range of standard mass spectrometers. This powerful research tool is the newest addition to CEC's mass spectrometer line—foremost in the field for over twenty years. Included in today's complete line are:

21-103C MASS SPECTROMETER—Time-proved international standard—performs control and laboratory analyses to above mass 600 for gases, liquids, and high-vapor pressure solids. ***Bulletin CEC 1800-X1.***

21-130 LABORATORY MASS SPECTROMETER—Medium-priced with performance equal to that of larger units over a reduced mass range. Ideal for most laboratories. ***Bulletin CEC 21130-X1.***

21-620A PROCESS-MONITOR MASS SPECTROMETER—Continuous sampling for process monitoring... provides fastest qualitative and quantitative analysis of gaseous and low-boiling liquid streams. Also adaptable as low-cost mobile batch analyzer. ***Bulletin CEC 1824-X1.***

21-611 MASS SPECTROMETER—Smallest in the line, portable, excellent for assignment to special projects, or adaptation for residual-gas analysis. Sensitivity equals the 21-103C. ***Bulletin CEC 1843-X1.***

Actual photo-plate record from the 21-110 shows three mass spectral lines resolved at m/e 28. The two closest lines represent ions of CO and N_2 which differ by only 0.01123 mass units.

Circle 2062 on Page 48-B

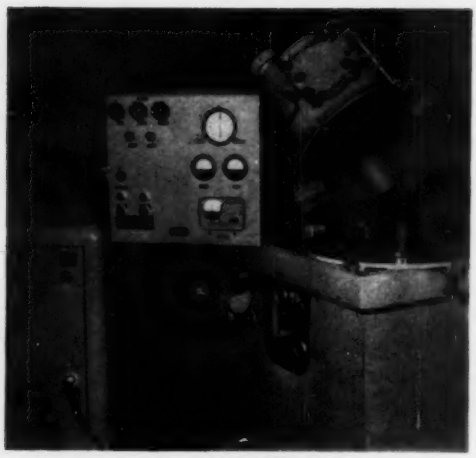
21-110 Series provides a selection of modular ion sources and ion detectors for different applications. Conversions can be made easily by operator. Bulletin CEC 21110-X1.

Analytical & Control Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · *FINER PRODUCTS THROUGH IMAGINATION*

THE ZAK VACUUM BUTTON FURNACE
A COMPACT UNIT FOR EXPERIMENTATION, QUALITY CONTROL, OR SMALL PRODUCTION AND LABORATORY MELTS



The Zak Vacuum Button Furnace is a versatile laboratory furnace to be used with controlled atmosphere or vacuum melting according to the needs of the user. Some melters find it invaluable in testing for quality control of purchased sponge or platelets; others find by threading a few pounds of compacted material into the electrode holder a hand fed consumable electrode melt can be obtained. Yet, if required the furnace can be equipped with a small power ram.

The Zak Furnace may be purchased as a Basic Unit or complete with Control Panel, Gauging and Pumping Systems. Whatever your requirements may be we will quote to your specifications.

Send today for descriptive literature: B6UO-2 Button Furnace • CR-58 Crucible • FAC-58 Facilities Folder • IM-59 Ingot Molds • HT-59 Hot Topping Unit.

"Engineering Manufacturers for Industry"

ZAK MACHINE WORKS, INC.

TROY (GREEN ISLAND) NEW YORK

Circle 2063 on Page 48-B

Inspection and Control Equipment

Vibratory Polishing

An untrained technician can obtain excellent surfaces on metal samples – from soft gold to hard boron carbide – with the "Vibromatic" polisher. Hand-polishing drudgery and waste are eliminated. Polishing is continuous, clean and completely nondirectional. There is no relief polishing, smearing, or "shadowing" which may occur with hand polishing. The technician is free to mount samples and make photomicrographs during polishing operation. *Fisher Scientific Co.*

For further information circle No. 1780 on literature request card, p. 48B

Push-Pull Gage

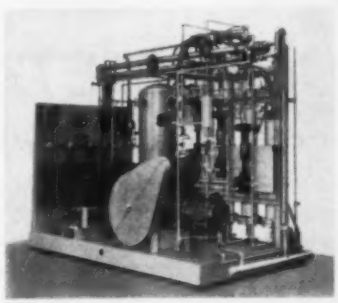
A split-dial on this instrument gives readings of compression, tension, or oscillating loads. A complete line of gages are available, calibrated in capacities ranging from 5-0-5 to 25,000-0-25,000 lb. The instruments are accurate within ±1% of full-scale reading. Applications include measuring tension in moving wire, preventing conveyer system overload, and setting spring adjustments. *W. C. Dillon & Co., Inc.*

For further information circle No. 1781 on literature request card, p. 48B

Production Equipment

Hydrogen Generator

This plant produces low-cost hydrogen in two stages: dissociation of ammonia into H_2 and N_2 and separation of H_2 by a continuously cycling adsorption process. The hydrogen content can be controlled from 82 to 98%, the balance being nitrogen. Contamination of hydrogen with CO or CO_2 is impossible. The plant can be operated in any range from 25% to full capacity (750 scfh.) without affecting quality or efficiency. *Electric Furnace Co.*



For further information circle No. 1782 on literature request card, p. 48B

Parts and Forms for Design and Applications

Galvanized Spring Wire

The zinc coating on music wire has been increased to 3-7% of the total weight and is 10 to 15 times more corrosion resistant than standard tinned wire. Post-plating, with the risk of acid embrittlement and tangling, is eliminated. Close-pitched springs are uniformly protected around their circumference. The wire (0.012 to 0.060 in. in diameter) is made to standard music wire specifications. *National Standard Co.*

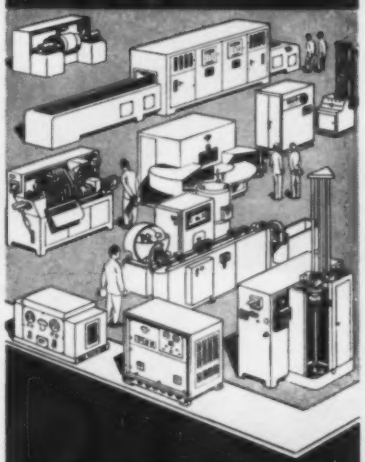
For further information circle No. 1783 on literature request card, p. 48B

Corrugating Metal

A new concept in corrugating – folding metal rather than drawing it – allows simultaneous perforating, offsetting and slotting, and affords a large variety of patterns in aluminum, brass, copper, stainless or mild steel. The machine takes coiled stock in widths up to 36 in. and gages from 0.002 to 0.030 in. Applications include air conditioners, space heaters, waveguides, curtain walls, and shipping containers. *Twin Coach Co.*

Circle No. 1784 on request card, p. 48B

for HARDENING • BRAZING
SOLDERING • FORGING • ANNEALING
MELTING • SINTERING • WELDING
REFINING • SHRINK FITTING
CRYSTAL GROWING



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Manufactures the most complete range of

INDUCTION HEATING EQUIPMENT

ELECTRONIC · LOW FREQUENCY
MOTOR GENERATOR

THER-MONIC features

• Over 20 years of concentrated experience.

• Over 5,000 installations.

• Over 15,000 heating applications resolved in our customer service laboratories.

• This outstanding experience and know-how qualify us to prescribe the techniques and equipment best suited for your requirement.

Contact our factory or your local IHC representative.

Write for New 56-page catalog of exclusive features, facts and specs.

INDUCTION HEATING CORP.
181 WYTHE AVE., BROOKLYN 11, N. Y.

Circle 2064 on Page 48-E

the new Leitz **MICRO-METALLOGRAPH**

engineered specifically for modern industry

Availability of a Le Chatelier type LEITZ MICRO-METALLOGRAPH has been eagerly awaited by industrial scientific laboratories. With this new instrument, precise details of metallurgical specimens may be viewed simultaneously on the 30" projection screen as well as through the binocular observation tube. The newly-developed, powerful XENON lamp provides ample illumination to permit observation in a normally lighted room. Photomicrography of specimens is quickly and easily accomplished with pre-aligned 5" x 7" camera or, if desired, a Polaroid-Land 4" x 5" camera back. Engineered specifically to meet the needs of the modern, metal working industry the new LEITZ MICRO-METALLOGRAPH "sets a new standard for metallurgical observations."

- Inverted microscope stand with mechanical stage, coarse and fine focusing
- Xenon lamp with 7 filters in push-button, quick-change mounts
- Eye pieces with 30% wider field, in binocular tube
- New, "Plano," flat-field objectives from 3.2 to 160x
- Projection and viewing screen in cast housing, 30" diameter
- Special 5"x7" camera with adaptor for attaching Polaroid-Land 4"x5" camera back

Leitz

FIRST IN PRECISION OPTICS

20859

E. LEITZ, INC., 468 PARK AVENUE SOUTH, NEW YORK 16, N. Y.
Distributors of the world-famous products of Ernst Leitz G. m. b. H., Wetzlar, Germany—Ernst Leitz Canada Ltd.
LEICA CAMERAS · LENSES · PROJECTORS · MICROSCOPES · BINOCULARS

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468 PARK AVENUE SOUTH, NEW YORK 16, N. Y.
Please send me additional information on the new MICRO-METALLOGRAPH, Model MM.

Name _____

Street _____

City _____ Zone _____ State _____

Circle 2065 on Page 48-B

Patents Pending

Presenting-

Bilt-Up Baskets

Now available- **AECCo**

Standard Basket Parts

adaptable to a wide range of furnace trays

NEW DESIGN features of **AECCo. BILT-UP** components are now combined with the **PROVEN ADVANTAGES** of **AECCo. "CRISS-CROSS"** construction for tray baskets—another illustration of **AECCo. BETTER SERVICE**

- Many sizes easily BILT-UP from AECCo. STANDARD BASKET PARTS
- Parts individually replaceable—longer service at lower cost
- Length and height variable in one-inch increments
- Light weight combined with high strength
- Positive—and strong—cast connections at all points
- Inherent flexibility at joints for better adjustment to thermal stresses
- Better atmosphere circulation for improved uniformity of work processed

RECTANGULAR TRAY
WITH
BILT-UP BASKET
9⅝" HIGH

SQUARE TRAY
WITH
BILT-UP BASKET
12-5/16" HIGH

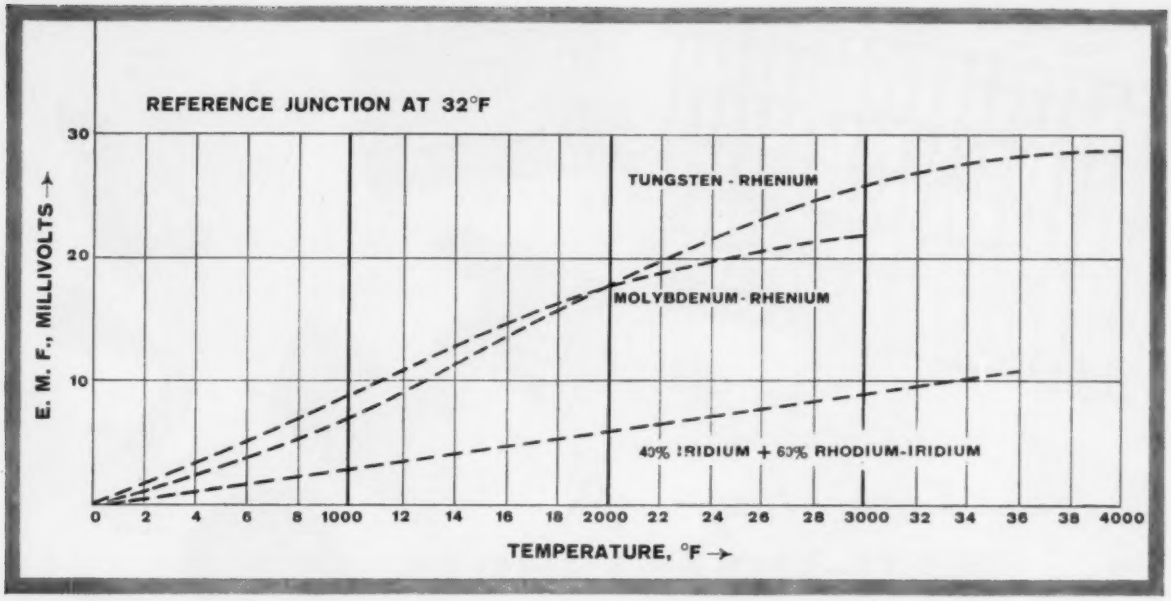
HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING CO.

1700 W. WASHINGTON ST., CHAMPAIGN, ILL. TELEPHONE FLEETWOOD 6-2568

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Circle 2066 on Page 48-E


REFERENCE JUNCTION AT 32°F
E. M. F., MILLIVOLTS →
30
20
10
TUNGSTEN - RHENIUM
MOLYBDENUM - RHENIUM
40% IRIDIUM + 60% RHODIUM-IRIDIUM
0 2 4 6 8 1000 12 14 16 18 2000 22 24 26 28 3000 32 34 36 38 4000
TEMPERATURE, °F →

Measure temperatures up to 4000°F with Honeywell Thermocouples

Precise measurement of high temperatures is almost an art. Working effectively with temperatures over 2800°F calls for an intimate knowledge of both materials and methods. Honeywell's long experience, combined with an intensive basic research program, have produced special techniques and equipment for precise measurement of high temperatures.

The thermocouples listed below—tungsten-rhenium, molybdenum-rhenium, and 40% iridium + 60% rhodium-iridium—are the best available combination of calibration stability, reproducibility and physical strength. Although the temperature-emf curves shown above are still tentative, they are based on substantial scientific studies conducted independently in several different laboratories.

Honeywell's research at the Hopkins Research Center is aimed at discovering more and more practical information on high-temperature thermocouples and passing the results on to you.

For more information, call your Honeywell Field Engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Control

SINCE 1885

*HIGH TEMPERATURE ASSEMBLIES WITH PROTECTING TUBE**

Calibration	Maximum Recommended Temperature	Tube & Insulator Material	Tube Dimensions I.D. (in.)	Tube Dimensions O.D. (in.)
TUNGSTEN-RHENIUM	3200°F	ALUMINUM OXIDE	3/16	5/16
	4000°F	BERYLLIUM OXIDE	1/4	3/8
MOLYBDENUM-RHENIUM	3000°F	ALUMINUM OXIDE	3/16	5/16
40% IRIDIUM+ 60% RHODIUM-IRIDIUM	3200°F	ALUMINUM OXIDE	3/16	5/16
	3600°F	BERYLLIUM OXIDE	1/4	3/8

*HIGH TEMPERATURE ASSEMBLIES WITHOUT PROTECTING TUBE**

Calibration	Maximum Recommended Temperature	Insulator Material	Insulator Dimensions I.D. (in.)	Insulator Dimensions O.D. (in.)
TUNGSTEN-RHENIUM	3200°F	ALUMINUM OXIDE	0.028	0.140
	4000°F	BERYLLIUM OXIDE	0.028	0.130
MOLYBDENUM-RHENIUM	3000°F	ALUMINUM OXIDE	0.028	0.140
40% IRIDIUM+ 60% RHODIUM-IRIDIUM	3200°F	ALUMINUM OXIDE	0.028	0.140
	3600°F	BERYLLIUM OXIDE	0.028	0.130

*Most assemblies available in 5", 11", 17", 20", 23" and 29" immersion lengths.

Circle 2067 on Page 48-B

In the shape, length,

diameter you need:

ASARCON®

Continuous-Cast Bronze Castings

Asarco will custom cast practically all standard tin-bronze alloys in the shapes, lengths, and diameters you need. You get custom shapes in continuous lengths; uniformity and machinability of alloys guaranteed free of hard or soft spots, with no sand, dirt, or dross to dull tools or reduce cutting speeds. You get the superior physical characteristics of continuous cast bronze: impact, tensile, yield strength and hardness, as much as 100% better than the same alloys cast other ways. Write for complete data to Continuous-Cast Department, American Smelting and Refining Company, Barber, N. J. or Whiting, Ind.

Immediately available from stock:

ASARCON 773 BEARING BRONZE (SAE 660)—260 sizes of rods and tubes. Complete range of sizes from ½" to 9" diameters, up to 105" lengths.

ASARCO

AMERICAN SMELTING AND REFINING COMPANY

CONTINUOUS CAST DEPARTMENT

Bronze part illustrated was machined from a hexagon shaped continuous-cast tube. This custom-cast shape was produced precisely to the customer's alloy, shape and dimension specifications.

West Coast Distributor: Kingwell Bros., Ltd., 457 Minna Street, San Francisco, Calif. In Canada: Federated Metals Canada, Ltd., Toronto and Montreal. Distributors in many principal cities.

Circle 2068 on Page 48-8

SOLID-WALL INSULATION
Highest quality graded fire-brick and block insulation. Greatly reduces heat loss, maintenance and operating costs.

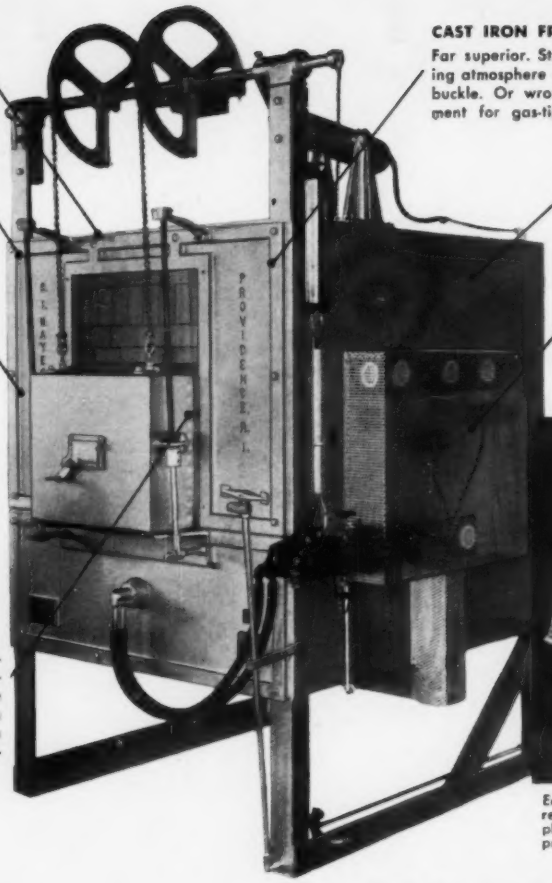
SYNTHETIC MULLITE REFRACTORIES
Outlast all other refractories many times over. Extra stable at high temps — won't slump, crack, spall.

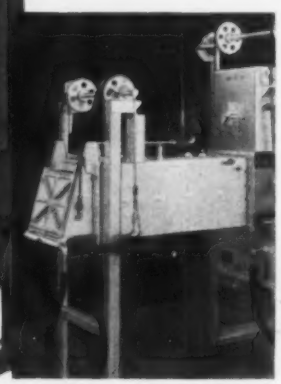
LOW-WATT DENSITY HEATING ELEMENTS
Nickel chromium ribbon or new thru-type ceramic rods. Extra long life — minimum of hot spots, arcing, fusing.

CAST IRON FRONT PLATE
Far superior. Stands up in burning atmosphere — won't warp or buckle. Or wrought steel weldment for gas-tight construction.

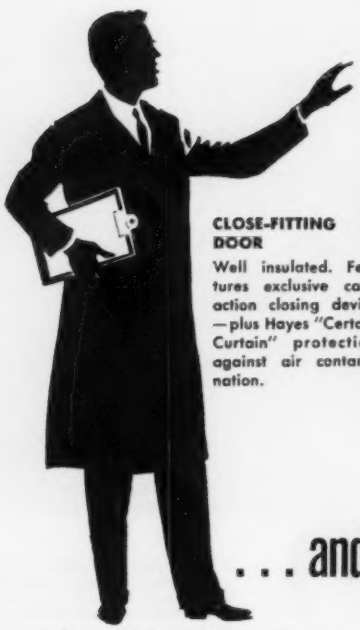
GAS-TIGHT SHELL
Reinforced steel plate. Compact, extra-sturdy, maintenance-free design.

AUTOMATIC TEMPERATURE CONTROL
Includes controls, thermocouple and leads, magnetic contactor. Wide choice of accessories.





Easily adapted to critical work requiring low dewpoint atmospheres, by addition of muffle and pre-heat chamber.



CLOSE-FITTING DOOR
Well insulated. Features exclusive cam-action closing device — plus Hayes "Certain Curtain" protection against air contamination.

. . . and talk about furnace FLEXIBILITY!

Versatility multiplies the value and economy of any good heat treating furnace. That's why Hayes Standard Type LR Preheat and CG Superheat Furnaces are designed to handle almost limitless hardening and annealing applications. Used with Hayes external generating equipment, these two furnaces are readily adaptable to reducing, as well as oxidizing atmospheres . . . for treating virtually all types of steels and many non-ferrous metals.

Both the Hayes LR Preheat Furnace and the CG Superheat Furnace are often called "spare tire" furnaces. Each features Hayes patented "Certain Curtain" atmosphere control, which acts as an *emergency stand-by* when external gas generating equipment is not in use.

Before you select *any* furnace, compare it with Hayes for job flexibility . . . plus operating economy . . . plus *all* these quality-construction advantages!

Results Guaranteed!

Write today for Bulletin 461

ELECTRIC CERTAIN CURTAIN FURNACES

C. I. HAYES, INC.

Established 1905

802 WELLINGTON AVE. • CRANSTON 10, R. I.

Circle 2069 on Page 48-B

NEW LITERATURE

Ferrous Metals

1786. PH Stainless
Armco Steel Corp. will send data on 17-4PH stainless steel. Stronger than Type 416; as corrosion resistant as 18-8 stainless steel.

1787. Alloy Steel Booklet
"Quick Facts About Alloy Steels" published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

1788. Steel for Springs
Brochure from *Sandvik Steel, Inc.* covers properties and product information on spring steels.

1789. Property Charts
Wallace Barnes Steel Div. has published "Physical Property Charts" on properties and formability of tempered steel.

1790. Nitriding Steels
National Forge Co. will send Bulletin NH1058 on nitriding steels, including the 5% Ni-2% Al grade.

1791. Stainless Products
Booklet, "Producing Stainless Steels", describes plates, heads, forgings and special shapes produced by *G. O. Carlson.*

1792. Steel Plate
Folder from *U. S. Steel* presents properties and selection data on carbon steel, high-strength low-alloy steel, "T-1" steel and stainless steel plates.

1793. Spring Steels
The *Uddeholm Company of America, Inc.* has published a 50-page Catalog and Stock List on spring steels made of straight carbon steels, alloy steels, and stainless steels.

1794. Toolsteel Guide
A "Steelector" booklet from *Allegheny Ludlum* gives complete data on line of toolsteels . . . mechanical property and heat treating information included.

Nonferrous Metals

1795. Vanadium Alloys
Brochure VM2-P8 describes vanadium mill products made by *Union Carbide Metals Co.*

1796. Drawn Copper Shapes
Flyer from *Nippert Electric Products Co.* describes standard and special shapes produced to your specifications.

1797. Aluminum Castings
Bulletin 103 from *Federated Metals Div.* discusses properties and characteristics of "Tenzaloy", a self-aging aluminum casting alloy. No heat treatment required.

1798. Brass Die Castings
Titan Metal Manufacturing Co. offers information on pressure die castings in a range of brass alloys.

1785. Information Searching
Brochure discusses A.S.M.'s Documentation Service which delivers the world's current metallurgical literature to you every

two weeks in digest form. Bibliographic searching of previously published information covering the area of your particular interest is also available. *American Society for Metals.*

1799. "Tin News"
A monthly bulletin on tin supply, prices, and new uses is published by the *Malayan Tin Bureau.*

1800. Rare Earths
Vitro Chemical Co. has published a pamphlet on rare earths, including scandium and yttrium.

1801. W and Mo
Information on tungsten and molybdenum ingots and billets from *Sylvania Electric Products, Inc.*

1802. Beryllium Products
Bulletin from *Beryllium Corp.* describes facilities for the production and fabrication of beryllium products, also research and development.

1803. Selection Chart
Seymour Manufacturing Co. is offering an "Alloy Selection Chart" for nickel silver, phosphor bronze, brass, copper, and stainless steel.

1804. Wire, Rod and Strip
Information from *Riverside-Alloy Metal Div.* on supplies of nickel, nickel silver, cupronickel, stainless, and bronze—in strip, rod, and wire.

1805. Tungsten Chemicals
Sylvania Chemical and Metallurgical Div. has issued a new tungsten chemicals specification catalog.

1806. Impact Extrusions
Alcoa has published a 34-page brochure on impact extrusions entitled "Metal in Motion" which details applications and savings possible.

1807. Inert Fabrication
12-p. brochure published by *Universal-Cyclops Steel Corp.* is entitled "InFab for Producing Space-Age Metals".

1808. Stock Catalog
290 pages of stock information on nonferrous and stainless steel mill products. Latest government and society specifications included. Data from *Meier Brass & Aluminum Co.*

1809. Tin Applications
20-p. booklet released by *Malayan Tin Bureau* contains descriptions of many tin applications, including tin plate, solder, bronze, babbitt, white metal, tinning, tubes, and chemicals.

1810. Conductivity Rating
8-p. bulletin provides a rapid check list for electrical conductivity ratings of 56 copper alloys. *Bridgeport Brass Co.*

1811. Copper Alloys
Data sheet from *American Metal Climax, Inc.* discusses "Amzirc" a new zirconium-copper alloy which combines high conductivity with resistance to thermal impact.

1812. Molybdenum Products
General Electric Co. will send information on molybdenum in squares, rectangles, slabs, hollows or solid cylinders up to 1 ft. in diameter.

1813. "Ampco" Metal
Bulletin describes applications where severe wear and corrosion, or mechanical abrasion is encountered. *Ampco Metal.*

1814. Rare-Earth Metals
The *Lunex Co.* will send pamphlet describing the properties of high-purity rare-earth metals including lanthanum, yttrium, and gadolinium.

1815. Powder Metallurgy
Mueller Brass Co. has issued product data sheets covering the production and application of powder-metal parts.

Heat and Corrosion Resistant Materials

1816. High-Nickel Alloy
Duraloy Co. will furnish information on "HOM" casting alloy for the 1800-2300° F. range.

To request any item listed, circle appropriate number on Reply Card, p. 48B

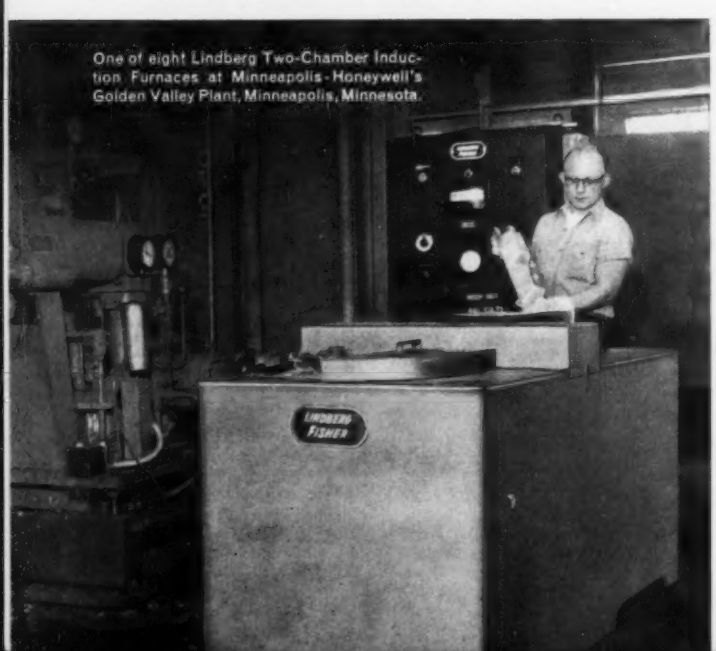
ART GEORGE has a good word to say for Lindberg Melting Furnace performance

QUOTE

Mr. Art George, Senior Production Engineer, Golden Valley Plant, Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.

"Our installation of eight* Lindberg-Fisher Two-Chamber Induction Melting and Holding Furnaces has given remarkable service for more than four years. In this period, with the help of a well executed Honeywell maintenance program, the installation has been unusually trouble-free. Only one of the eight furnaces has required relining over this long period. Handling more than 1,000,000 pounds of aluminum and zinc annually, the installation has unfailingly provided the consistently high quality of metal our precision instruments require."

**Altogether, 44 Lindberg Furnaces are in operation in various Honeywell plants.*



One of eight Lindberg Two-Chamber Induction Furnaces at Minneapolis-Honeywell's Golden Valley Plant, Minneapolis, Minnesota.

These eight Lindberg-Fisher Induction Furnaces melt and hold aluminum and zinc for die casting gas valve housings and other component parts. They are located at the die casting machines where ingot and scrap can be melted and held at the desired casting temperature in one convenient unit. Magnetic fluxing and stirring insures uniform temperatures and consistently clean metal.

In any production process where aluminum needs heat there is Lindberg equipment to apply it most economically and efficiently. Furnaces for melting and holding, casting stations, re-melting or heat treating are available in all capacities, electric or fuel fired. Get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg-Fisher Division, Lindberg Engineering Company, 2448 West Hubbard St., Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

Circle 2070 on Page 48-B

LINDBERG
heat for industry

1817. Refractory Grains

Catalog from *Norton Co.* describes a wide range of refractory materials. Physical, chemical, and electrical properties of Al_2O_3, MgO, boron carbide, and fuzed zirconia.

1818. Graphite Cloth

Bulletin 101 presents detailed property data on graphite woven fabrics and their applicability to a variety of industrial uses. Textile characteristics are also included. *National Carbon Co.*

1819. Heat Resistant Castings

12-p. brochure describes research, design, development and production of high-alloy heat resistant castings for the steel industry. *Electro-Alloys Div.*

1820. High-Alloy Castings

64-p. booklet "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications" available from *International Nickel Co.*

1821. Super Refractories

The *Carborundum Co.* has issued a booklet on refractories including "Refrax", a nitride-bonded silicon carbide.

1822. Alumina Tubes

Morganite Inc. will send data sheets describing porous, pure alumina tubes for temperatures to 3450° F. Can be used in hydrogen and cracked ammonia reducing atmospheres.

Nuclear Materials

1823. Stainless Pipe

Flyer from *Sandusky Foundry and Machine Co.* discusses centrifugally cast austenitic stainless steel pipe for use as pressure piping in nuclear service.

Tool Materials

1824. Wire Drawers

The *Ajax Manufacturing Co.* has prepared Bulletin 111-B on an "Ajax-Hogue" wire drawer. It will cold-draw wire from hot-rolled stock.

1825. Chemical Milling

Eastman Kodak Co. has a brochure which presents information on "Metal-Etch Resist". It speeds up and simplifies chemical milling operations.

1826. Drawing Lubricant

Bulletin 26 discusses "Fleximet S", a multi-purpose, dry-film lubricant used in drawing ferrous and nonferrous alloys. *Swift & Co.*

1827. Roll Forming

88-p. booklet from the *Yoder Co.* contains data on cold roll forming equipment, processes, and products.

1828. Colloidal Dispersions

Bulletin 425 "Colloidal Dispersions for Use in Metal Casting" available from *Acheson Colloids Co.*

1829. Draw Forming

The *Cyril Bath Co.* offers literature describing radial draw forming machines for high-speed production.

1830. "Moly" Lubricant

The *Alpha-Molykote Corp.* will send a free sample of "Molykote G" lubricant plus their Bulletin 126 describing the product.

1831. Graphite Dispersions

Booklet explains the proper oil or water-base graphite dispersion for your specific operation or application. *Grafo Colloids Corp.*

1832. Molybdenum Disulphide

24-p. Bulletin 124 discusses the theory and practice of lubrications by solids, including advantages of using molybdenum disulphide solid lubricants. *Alpha-Molykote Corp.*

1833. Carbide Catalog

44-p. Catalog TTI-60 includes specifications and general information on "Firthite" carbide tips, tools, tool-holders and inserts. *Firth Sterling.*

1834. Solid Film Lubricant

Flyer available from *Hohman Plating & Mfg. Inc.* on "Surf-Kote No. A-1290" air-drying solid-film lubricant.

Industrial Heating Equipment

1835. Salt Baths

"Salt Bath Tips and Trends", Vol. 12, No. 2, discusses operational details of a recent high-speed salt bath installation. *Ajax Electric Co.*

1836. "Temperature" Crayons

Tempil Corp. has information on "Tempilstiks", available in 80 different temperature ratings.

1837. Box Furnaces

Bulletin GED4179 from *General Electric Co.* on box furnaces for production heat treating, tool rooms, laboratories, and pilot operations.

1838. Salts for Heat Processing

Information from *E. F. Houghton & Co.* on salts for martempering, annealing, carburizing, nitriding, hardening, and quenching.

1839. Induction Heating

The *Ohio Crankshaft Co.* has published "Typical Results of TOCCO Induction Heating for Forging and Forming".

1840. Combustion Tubes

For service up to 3000° F., *McDanel* combustion tubes—made of mullite or "Zirco" ceramics—are thermal shock resistant and gas tight.

1841. Heat Treating Materials

Park Chemical Co. has information on a complete line of heat treating materials for carburizing, hardening, heating, or quenching.

1842. Direct-Reading Pyrometer

The "Shawmeter" is an automatic, direct-reading, two-color pyrometer for indicating, recording, or controlling temperatures to 6500° F. Data from *Shaw Instrument Corp.*

1843. Quenching Oil

Information on "Voluta" quenching oils can be obtained from *Shell Oil Co.* Stable at temperatures to 180° F.

1844. Gas Burners

Catalog covers line of "Buzzer" burners. No blower or other power needed—just connect to gas supply. *Chas. A. Hones, Inc.*

1845. Surface Pyrometer

Catalog No. 168 describes "Pyro" surface pyrometer. Quick-acting . . . precise . . . easy-to-read dial. *Pyrometer Instrument Co.*

1846. Heat Exchanger

Niagara Blower Co. has released Pamphlet 120 covering "Aero" heat exchangers to control the temperature of your quench bath.

1847. Thermal Fatigue

Electro-Alloys Div. has published "The Mechanism of Thermal Fatigue" by H. S. Avery.

1848. Gas Alloying

Lee Wilson Engineering Co. will send folder covering the "open coil" process of gas alloying.

1849. Radiant Tubes

The *Pressed Steel Co.* has released a pamphlet covering sheet alloy radiant tubes which cost less and last longer than other types.

1850. Electronic Generators

Catalog describes electronic tube generators from 1-100 kw. and spark-gap converters from 2-30 kw. *Lepel High Frequency Laboratories.*

1851. Draw Furnace

Bulletin SC-182 describes continuous draw furnace with high-speed, high volume air circulation. Information from *Surface Combustion Div.*

1852. Low-Temperature Cabinet

Revco Inc. has issued folder "Selecting a Low-Temperature Cabinet." Temperatures to −140° F.

1853. Temperature Controller

Honeywell has data on "Model T654A, a low-cost indicating temperature controller for use in rugged industrial applications.

1854. Oil Coolers

Combined Catalog and Selection Manual gives full information on *Bell & Gossett Co.* self-contained oil coolers for quenching systems.

1855. Process Belts

Ashworth Bros., Inc. has issued literature on metal process belts for all types of applications involving continuous flow.

1856. Induction Melting

Inductotherm will send Bulletin 70 on induction furnaces for fast, clean melting operations.

1857. Industrial Ovens

Young Brothers Co. offers Bulletin 157 on dependable heat treat ovens, designed and built for individual product and process requirements.

1858. Gas Analyzer

Information can be obtained from *Mine Safety Appliances Co.* on an inert gas analyzer which includes a controller and recorder.

1859. Program Control

Process Data Sheet 660 discusses "Master-Slave" program control for reproducing heat treating cycles accurately. *Leeds & Northrup.*

1860. Industrial Blowers

Catalog 126B from *Spencer Turbine Co.* contains complete specifications on blowers, available in standard capacities (½ to 1000 hp.), up to 20,000 cfm., and 4 oz. to 10 lb. pressure.

1861. Heating Elements

Information from *Carborundum Co.* on "Globar" silicon carbide heating elements for precise, economical bright annealing and other heating applications.

1862. Salt Baths

Eliminate scaling and decarburization in heat treating without special atmospheres—through the use of salt baths. Data available from *American Cyanamid Company.*

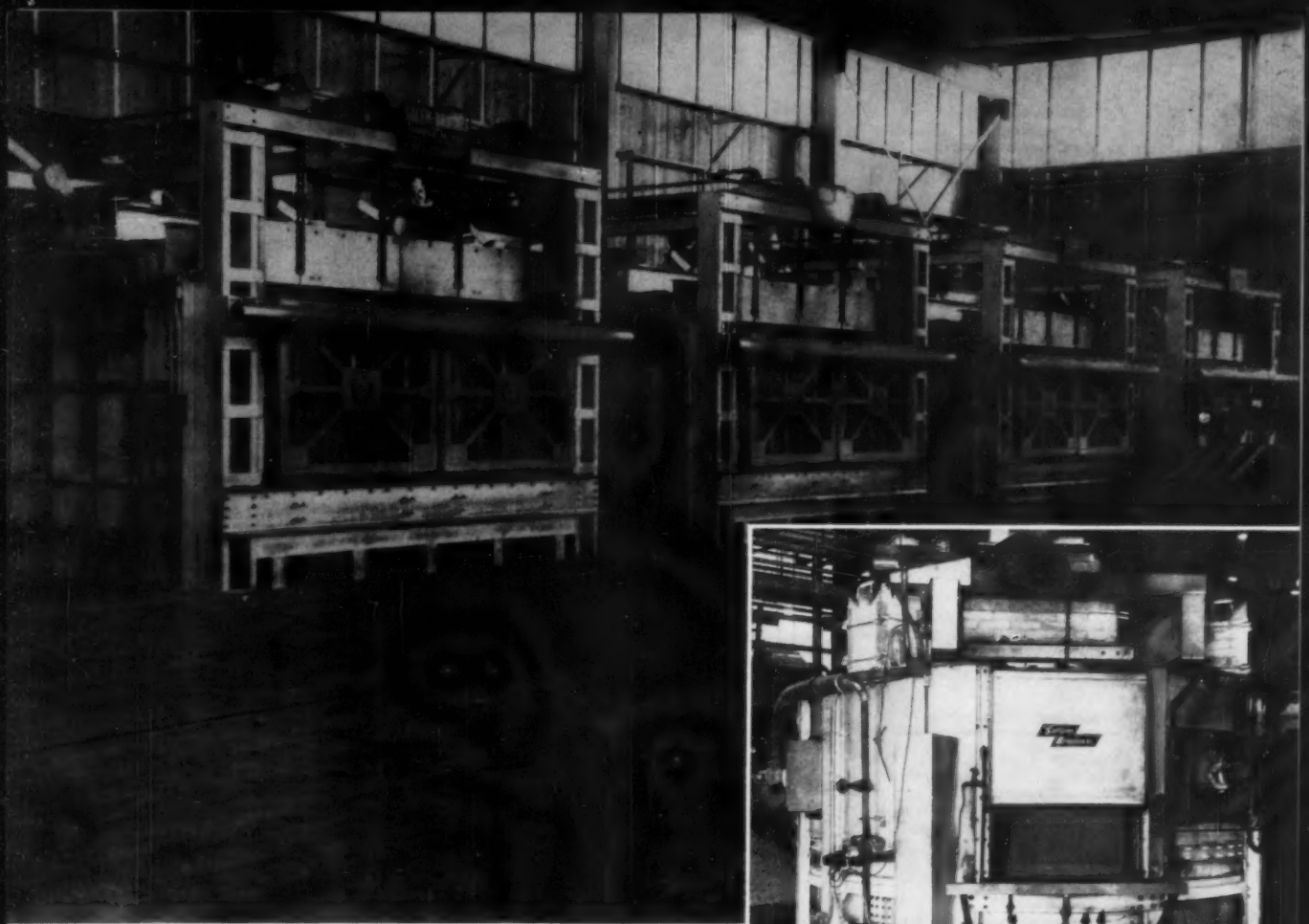
1863. Heating Element Alloy

A report from *Hoskins Mfg. Co.* describes the results of a 5-yr. metallurgical research and development study on heating element alloys for controlled atmosphere furnaces.

1864. Resistance Furnace

Flyer from *Curtiss-Wright Corp.* describes high-temperature resistance furnace for laboratory research work. Temperatures to 4800° F. are possible; 5100° F. for intermittent use.

To request any item listed, circle appropriate number on Reply Card, p. 48B



Forge shops save money and increase production with these Salem-Brosius furnaces

Salem-Brosius furnaces are favorites in shops that forge stainless steels, titanium, zirconium, aluminum, and many of the refractory alloys used in jet engines and missiles, as well as the full range of carbon steels generally employed. The battery of batch furnaces above is now in continuous operation in the plant of one of the nation's outstanding forgers of newer alloys. The rotary hearth furnace below heats bar stock for closed-die automotive forgings.

Forge shop operators specify Salem-Brosius furnaces because they are built for long service life with common-sense structural, refractory, and mechanical characteristics. Designed for manual or automatic charge and discharge, rotaries such as this offer efficient, low-cost heating. They can be manually or automatically controlled, and offer assurance of fast and uniform output at high speed in a minimum of floor space.

Whether you require these or any other type of heating or heat-treating furnaces, Salem-Brosius can build them. Call us today.

Salem-Brosius, Inc.

PITTSBURGH, PENNSYLVANIA

Circle 2871 on Page 48-8

Salem-Brosius (Canada) Limited, Rexdale, Ontario • Salem-Brosius (England) Limited, London and Milford, England
Salem-Brosius (France) S.A., Paris, France • Salem-Brosius (Luxembourg) S.A. • Alloy Manufacturing Corp., Pittsburgh, Pa. • R. H. Freitag Manufacturing Div., Akron, Ohio • General Ionics Corp., Pittsburgh, Pa.

1865. Photoelectric Temperature Control

Bulletin 5108 describes photoelectric temperature-control line, "PyroTemp", a temperature-limiting device for controlling industrial processes. *The Clark Controller Co.*

1866. Industrial Furnaces

Catalog describes "Dyna-Trol" furnaces and ovens; complete specifications and price list for a full line of furnaces. *L and L Mfg. Co.*

1867. Temperature Control Instruments

Folder 3020 lists pressure gauges, thermometers and control instruments offered by *U.S. Gauge Div.*

1868. Production Carburizing

Ipsen Industries has bulletin P-59 describing pusher furnaces. Features include an enclosed charging mechanism and a chain discharging mechanism.

1869. Pulsation Burner

Bulletin No. 60-A from *E. W. Bliss Co.* describes pulsation burner. It can attain temperatures of 3450° F. and gives a faster heating cycle and increased fuel economy.

1870. Wall Chart

The *Claude S. Gordon Co.* will send Tempil's "Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color.

1871. Vacuum Furnaces

The *C. I. Hayes, Inc.* publishes bulletins 5709A and B describing "Vacu-Master" furnaces for conventional and special applications, such as sintering at temperatures to 4600° F.

1872. Heat Treating Furnace

The *Commercial Steel Treating Corp.* has literature on a gantry-type heat treating furnace. It can process parts up to 28 ft. long by 6 ft. in diameter.

1873. Shaker Hearth Furnaces

The *American Gas Furnace Co.* will send complete details on their "Automotion Series" rotary and shaker-hearth furnaces.

1874. Gas Furnaces

The *Harper Electric Furnace Corp.* publishes information on electric and gas furnaces for brazing, sintering, bright annealing and forging operations.

1875. Thermocouple Alloys

The *Hoskins Mfg. Co.* will send technical data sheets covering properties and applications of Chromel-Alumel thermocouples.

1876. Gas Generators

Rolock, Inc. has published literature describing an endothermic gas generator which features complete reversibility and self-cleaning of catalyst beds.

1877. Thermocouples

Catalog G100-4 discusses "Megopak" line of small diameter flexible thermocouples with high speed of response. *Minneapolis-Honeywell.*

1878. Indicating Controllers

Details available from *Barber Colman Co.* on "Wheelco Double-O" recording and indicating controllers.

1879. "Temperature" Pellets

The *Markal Co.* has published literature on "Thermomelt" temperature pellets for inaccessible or hard-to-measure applications.

1880. Thermostatic Bimetal

Booklet contains application data for more than 30 types of thermostatic bimetals. Available in strips, coils and completely fabricated elements of your design. *W. M. Chace Co.*

1881. Water Detector

Folder No. WS-60 describes installation and operation of "Water Sentinel", a safety device that detects water in enclosed oil quench tanks. *Ipsen Industries.*

1882. Bimetal Thermostats

4-p. Folder 8400 gives data on "Stemco" line of bimetal thermostats. Specification, performance and application data included. *Stevens Mfg. Co.*

Cleaning and Finishing Equipment

1883. Epoxy Pipe-Coating

Information on "Dearclad 765", an epoxy pipe coating which provides high electrical resistance and superior protection against chemical attack. *Dearborn Chemical Co.*

1884. Selector Brochure

Pocket-size brochure from *Macco Products Co.* tells how to select cleaners, cutting lubricants, drawing compounds, rust preventives and forging and extrusion lubricants.

1885. Maintenance Painting Guide

A 24-p. guide to maintenance painting of industrial plants, machinery and equipment, and commercial and institutional buildings has been published by *Sherwin-Williams Co.*

1886. Plating Aluminum

Bulletin TC-40221 discusses advantages of using metal fluoborates in plating aluminum. *Baker & Adamson Products.*

1887. Barrel Cleaning

Bulletin 660-A on "Clepo 11-T", an alkaline compound for cleaning, descaling

To request any item listed, circle appropriate number on Reply Card, p. 48B

℞ FOR INTERNAL INSPECTION

● **0.10" AND UP** . . . That's the point of entry requirement . . . to provide your inspectors the chance to use the outstanding National Fontar Borescope and thus give them the brightest, distortion-free, close-up view of the defect in "inaccessible" interior surfaces of the cast, drawn, welded or molded product . . . from inches deep to many feet.

Find out how its use can be a time and cost saver while it up-grades your Quality Control. Just send for our "Borescope Catalog."

ENGELHARD HANOVIA, INCORPORATED
NATIONAL ELECTRIC INSTRUMENT DIVISION
92-21 CORONA AVENUE • ELMHURST 73, NEW YORK

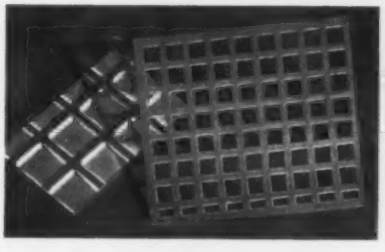
Circle 2072 on Page 48-B

NEW

DEEP-ETCH

MATERIAL FOR CHEMICAL MILLING

Kodak Metal-Etch Resist . . . speeds up, simplifies, opens new chemical milling applications



This photo sensitive resist ends time-consuming handwork, allows close-limit accuracy in deep-etch weight reduction and parts manufacture. Also reproduces fine-line detail as in plating, dial and nameplate making. Withstands acids, alkalies, electrolytic fluids . . . adheres well to aluminum, titanium, magnesium, stainless and other alloy steels. Makes volume production possible because of its high stability, strict uniformity. Send for detailed brochure: *Etching, Chemical Milling & Plating with Kodak Metal-Etch Resist.*

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EASTMAN KODAK COMPANY
Rochester 4, N. Y.

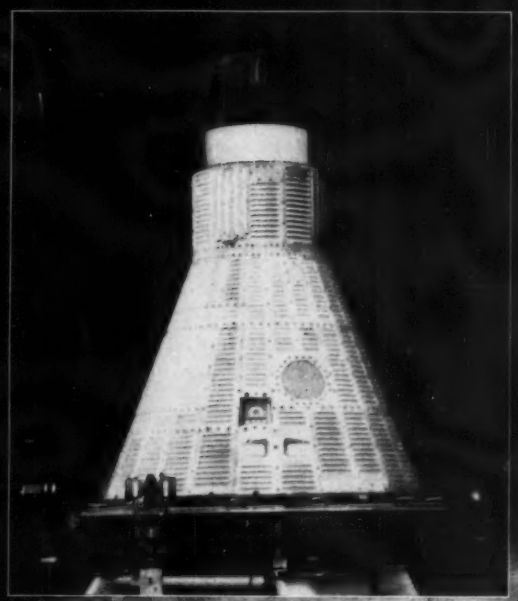
Kodak

Circle 2073 on Page 48-B

SIGNIFICANT ADVANCES IN BERYLLIUM TECHNOLOGY COME FIRST FROM BRUSH

FORGING INTO SPACE

Beryllium heat sinks are being readied for test flights.



Right now scientists and engineers from the National Aeronautics and Space Administration and McDonnell Aircraft are working toward the day when the first American will ride into space to orbit the earth.

How do beryllium and Brush fit into the Project Mercury manned space flight effort? A beryllium heat sink is one of two ways being tested to protect the precious human payload from re-entry heat. Beryllium absorbs tremendous heat, is light, yet maintains strength at high temperature. And Brush developed new techniques to produce the world's largest beryllium forgings for use as heat sinks in the tests to determine the final design of the manned space capsule.

Beryllium offers the solution to many 'space age' application problems. Brush will continue to take the lead in producing beryllium in new forms by new techniques for new uses.

Can this metal, its alloys, its oxide, or our expanding experience with these versatile materials solve a problem for you? Let us try. Contact us at 5209 Euclid Avenue or ENdicott 1-5400 in Cleveland, Ohio.

THE BRUSH BERYLLIUM COMPANY

and shine-rolling small steel parts. *Frederick Gumm Chemical Co.*

1888. Glass Shot

Microbeads, Inc. has published a brochure on microscopic glass beads—"Glasshot"—for use with all types of wet or dry blast equipment.

1889. Conversion Coatings

R. O. Hull & Company, Inc. has issued bulletins covering "Rodip" powders which offer a variety of low-cost finishing effects—brightening, corrosion protection, and paint bonding.

1890. Metal Abrasives

The *Cleveland Metal Abrasive Co.* will send catalog discussing "Realsteel" metal abrasives for your particular application.

1891. Cleaning Steel

Service Bulletin 80A presents information on cleaning steel prior to hot-dip galvanizing. *Oakite Products, Inc.*

1892. Chromium Chemicals

Solvay Process Div. will send Bulletin 52 describing chromium chemicals, including mutual chromic acid, 99.75% pure or better.

1893. Chromallizing

Bulletin PS from *Chromalloy Corp.* discusses chromallizing, a process of diffusing chromium with other elements into the surface of steel and other alloys for increased wear resistance.

1894. Rubberized Abrasives

Cratex Mfg. Co. has a catalog on rubberized abrasives for micro-deburring, smoothing, cleaning and polishing.

1895. Paint Stripping

Bulletin F-7893 from *Oakite Products, Inc.* describes a paint stripper for removing tough coatings—even epoxy finishes.

1896. Degreasing Solution

Hooker Chemical Corp. will send Bulletin 44A and Data Sheet 814 on "Nialk MD-grade" trichlorethylene—extra pure and low in cost.

1897. Conversion Coatings

Allied Research Products, Inc. will send Technical Data Files covering their "Iridite" process chromate coversion coatings for aluminum and magnesium.

1898. Phosphate Coatings

Turco Products, Inc. has published a booklet which contains a phosphating reference chart and full details on "Paintite" conversion coating processes.

1899. Vibratory Finishing

Use vibratory finishing for cleaning, descaling, deburring, grinding, radiusing, fine finishing, coloring and burnishing. Send part with exact finishing specifications for sample processing in *Pangborn Laboratory.*

1900. Combating Corrosion

Combat corrosion by using metals containing nickel. Send for publication No. A232 on "Corrosion Problems in Nuclear Reactor Power Stations". *International Nickel Co.*

1901. Barrel Finishing

The *Minnesota Mining and Mfg. Co.* has published a booklet describing "Honite" barrel finishing compounds, designed for all types of finishing operations.

Welding and Joining Equipment

1903. Hardsurfacing

Hardsurfacing can be applied to "high-wear" new parts and can recondition worn equipment. Information from *R. C. Mahon Co.*

1904. Fusing Welding

27-p. report from *Sciaky Bros. Inc.*, entitled "A Pictorial Report of Developments in Precise, Fully Automatic Fusion Welding Equipment".

1905. Electrode Data

20-p. booklet gives information on arc welding electrodes, including specifications, chemical requirements, and estimating electrode consumption. *National Cylinder Gas Div.*

1906. Welding Hardenable Steels

8-p. Bulletin SP-6A from *Taylor Winfield Corp.* describes the equipment and procedures recommended for spot welding hardenable steels.

1907. Plasma Spraying

Folder entitled "Plasma Bond Spraying Service" describes applications and fabrication techniques for metallic-ceramic coatings. *Thermal Dynamics Corp.*

1908. Iron Powder Electrode

Westinghouse Electric Corp. has information on "Zip-12" iron-powder electrodes designed for all types of structural and plate welding on wrought iron, low and medium-carbon steels, and cast steel.

1909. Silver Brazing

Bulletin 20 describes silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. *Handy and Harman.*

1910. Electron Beam Welding

The *NRC Equipment Corp.* will send information on electron beam welding, to help solve your tough welding problems.

1911. Brazing Furnaces

Eight-page brochure features complete line of brazing furnaces from laboratory

To request any item listed, circle appropriate number on Reply Card, p. 48B

HIGH PURITY **RARE EARTH METALS**

High purity rare earth metals of these properties can be used in pure form or in alloys — also can be machined, rolled or cast.

OTHER METALS PRODUCED
YTTRIUM
GADOLINIUM
LANTHANUM
PRAESODYMIUM
DYSPROSIUM
CHROMIUM

Properties of NEODYMIUM

Density	7.0
Brinnel Hardness	35
Melting Point °F	1880
Boiling Point	5970
Electrical Resistivity (55 F)	64.3
Thermal Conductivity (55 F)	9.0
Thermal Neutron X-section	46
Ultimate Tensil Strength psi	25,000
Yield Strength (as cast) psi	24,000
Ductile, Machinable	

For further information send for brochure.

LUNEX COMPANY
PLEASANT VALLEY 3, IOWA

Circle 2075 on Page 48-B

REVCO

ULTRA-LOW TEMPERATURE CABINETS

for

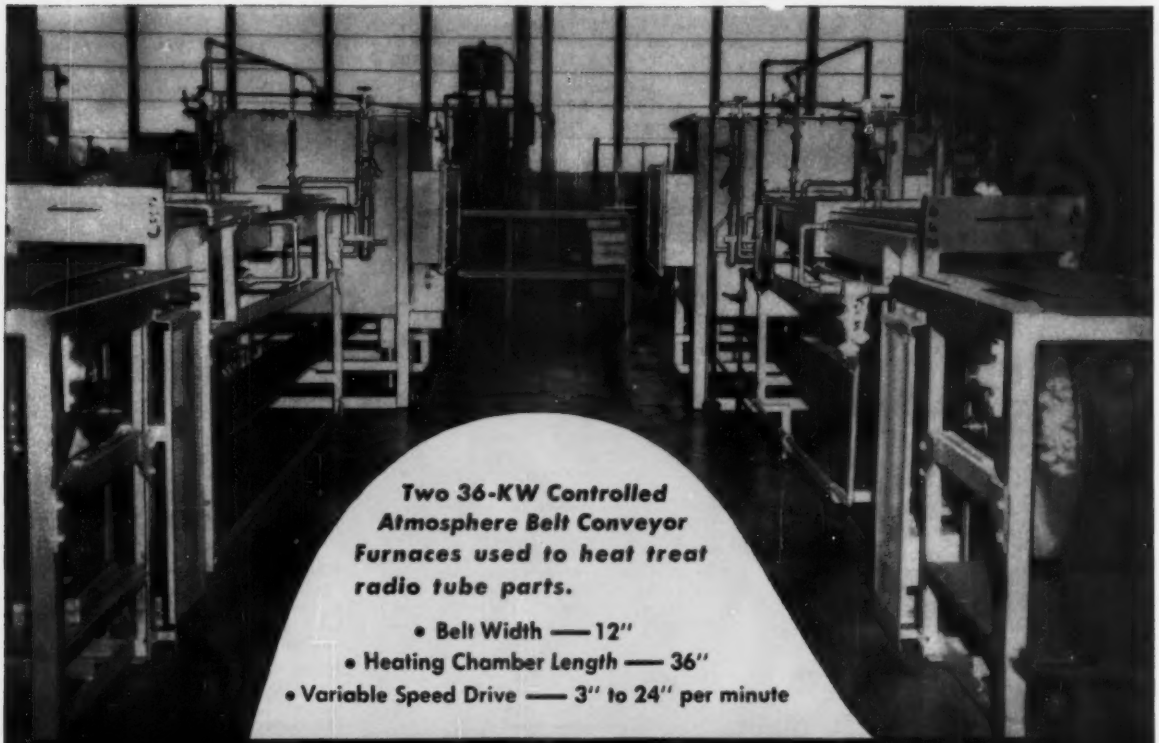
- Research
- Storage
- Seasoning
- Testing

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to −140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

For your FREE copy of the helpful folder, "Selecting a low temperature cabinet," write Revco, Dept. MP-110.

Industrial Products Div.,
REVCO INC.
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle 2076 on Page 48-B



Two 36-KW Controlled Atmosphere Belt Conveyor Furnaces used to heat treat radio tube parts.

- Belt Width — 12"
- Heating Chamber Length — 36"
- Variable Speed Drive — 3" to 24" per minute

Controlled Atmosphere CONVEYOR Furnaces

Drever controlled atmosphere type furnaces are available in many designs to suit applications where high quality surface and heat treating specifications are essential. Belt conveyor furnaces are designed with and without muffles, electrically heated and/or fuel fired.

Excellent temperature uniformities, with complete automatic temperature controls are maintained within narrow limits up to 2100°F.

We will be glad to supply you with complete information

DREVER COMPANY

RED LION RD. and PHILMONT AVE., BETHAYRES, PA.

22

Engineering and Manufacturing Facilities Around the World through Associates in France, Great Britain, Germany, Italy and Japan

Circle 2077 on Page 48-B

ovens to complex automatic giants. *Pacific Scientific Co.*

1912. Flash Welding

Booklet from *Asea Electric Co. Inc.* describes "Aseasvets" flash welding machine, which gives perfect welds regardless of operator skill.

1913. "Welding News"

Bimonthly publication of *National Electric Welding Machines Co.*, Vol. 12, No. 1, tells advantages of mash-seam welding for joining coil ends.

1914. Brazing Alloys

Vacuum melted brazing alloys can be used for bridging joint clearances up to 0.060 in. and for increasing production. Information is available from *General Electric Co.*

1915. AC Welder

Miller Mfg. Co. will send information on "Model M295" welder. Welding amperage ranges are 25 to 115 and 80 to 295 amp.

1916. Stainless Brazing

Stainless furnace brazing produces brazed joints as strong as parent metal. Information on stainless brazing facilities from *Wall-Colmonoy Corp.*

Inspection and Control

1917. "Edgegraphing"

16-p. data sheet explains Edgegraphing, a new technique for hand analysis of complex engineering data in 10, 20, or more variables. *Statistical Engineering Institute.*

1918. Hardness Testing

Reference book containing complete information on hardness testing. Easy-to-read text with many illustrations. *Clark Instrument, Inc.*

1919. Testing of Metals

Ten-page Bulletin M-2 from *Instron Engineering Corp.* covers all fields of precision metals testing.

1920. Stereophotomicrography

The *American Optical Co.* will send information on "Spencer 637" stereo-camera attachment for stereoscopic microscope.

1921. Physical Testing

To help solve your special problems in physical testing and save valuable time on vital projects. *Riehle Testing Machines Div.* will send three catalogs of interest.

1922. Spectroscopy

Pamphlet from *Radio Corp. of America* describes their horizontal goniomometer which performs six functions including counter-tube diffractometry.

1923. Research Metallographs

For routine work and advanced research *Bausch and Lomb* metallographs help industry boost output and maintain quality. Catalog E-240.

1924. Large Testing Machines

Tinius Olsen Testing Machine Co. will send 12-p. brochure describing large testing machines. Capacities to 5,000,000 lb. or more.

1925. Laboratory Balances

Burrell Corp. has published Bulletin No. 331 on "Ultramatic" laboratory balances. Single pan design, easy to operate.

1926. "Micrometallograph"

E. Leitz, Inc. has literature covering their Micro-Metallograph "Model MM." Metallurgical specimens may be viewed simultaneously on 30-in. projection screen as well as through binoculars.

1927. Pyrometer Equipment

Bristol offers complete data on pyrometers — electronic potentiometers, millivoltmeter, and radiation types.

1928. Portable Hardness Tester

Details from *Barber-Colman Co.* on "Impressor" portable hardness tester for rapid testing with no setup required.

1929. Mounting Sensing Elements

Norton Co. bulletin describes methods of mounting temperature and strain measuring elements by means of "Rokide" ceramic spray coatings.

1930. Magnetic Crack Detector

Information from *U.S. Casting Repair Corp.* on their portable "Model S-20 Seal-Lock" magnetic crack detector.

1931. Metallurgical Microscopes

Catalog 2H covers complete line of metallurgical microscopes and accessories for research, industrial and educational applications. *Unitron Instrument Co.*

1932. X-ray Diffraction

Picker X-ray Corp. will send folder discussing unique "Biplane Diffractometer" for X-ray diffraction analysis. Easier and faster to operate.

1933. Metallographic Preparation

William J. Hacker & Co. has published "Guide to Metallographic Preparation" plus literature describing polishing and grinding equipment.

1934. Portable Tensile Tester

Detroit Testing Machine Co. has information on hand operated, portable tensile tester—4000 lb. capacity. Hydraulic bench models up to 40,000 lb. capacity.

1935. Microsections

High-quality microsections are produced on a new unit with great saving of time to the operator. Fits low-speed polisher. Vol. 2, No. 1 of AB "Metal Digest" from *Buehler, Ltd.*

To request any item listed, circle appropriate number on Reply Card, p. 48B

Industry's NEWEST Production TOOL

MOLYKOTE® G LUBRICANT

- ALMOST 100% SAFETY AGAINST GALLING AND SEIZING WITH ALL BEARING METAL COMBINATIONS
- ELIMINATES STICK-SLIP, METAL PICK-UP AND DISTORTION IN PRESS FITTING
- REDUCES WEAR-IN TIME AND DAMAGE IN NEW OR REBUILT MACHINERY
- THE HIGHER THE LOADS, THE GREATER THE MARGIN OF SUPERIORITY OF MOLYKOTE G

Write for your free sample of MOLYKOTE G LUBRICANT today. We will also send you a copy of our new Bulletin 126 which gives complete details. THE ALPHA MOLYKOTE CORPORATION, 65 Harvard Avenue, Stamford, Conn. Phone: Fireside 8-3724. Plants in Stamford, Conn., Munich, Germany and Strasbourg, France.

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Please send me a free sample of your MOLYKOTE G Lubricant.
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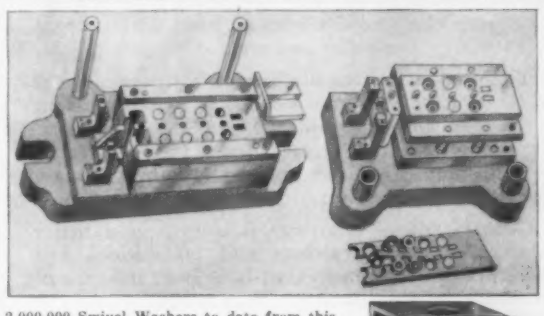
CITY_____ ZONE____ STATE_____

Circle 2078 on Page 48-B



2,000,000 Swivel Washers to date from this die made of PRK33 COBALTCROM TOOL STEEL, with at least 12,000,000 expected for life of die by this prominent manufacturer of Industrial bench, drafting board and desk lamps. Approximately 90,000 washers are produced between grinds, with stock removal of .0002" to resharpen.

Material blanked and formed is .012" Carbon Spring Steel.

PRK33 is equally efficient on thin gage and heavy gage stock, especially hot rolled, the abrasive scale of which is ordinarily death on cutting edges.

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ESTABLISHED 1911

ZIV STEEL & WIRE CO.

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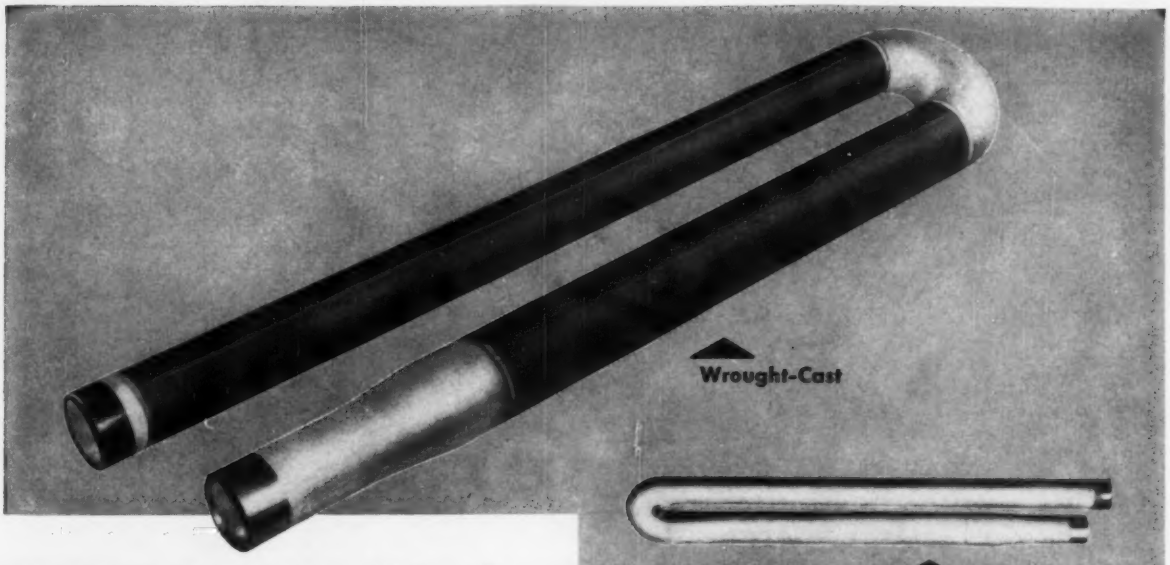
INDIANAPOLIS, IND. ST. LOUIS, MO. TOLEDO, O.
2945 W. HARRISON STREET — CHICAGO 12, ILL.

Circle 2079 on Page 48-B



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Unique General Alloys'

WROUGHT-CAST RADIANT TUBES

give consistent long life

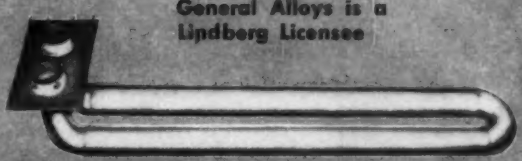
General Alloys' combination *Wrought-Cast* Radiant Tube Assemblies give consistent long life because they combine a *cast* return bend with straight tubes made from *rolled and welded plate.*

This design utilizes the erosion resistance of the casting where it is most needed . . . at the return bend. The uniform wall section of the plate forming the straight tube, and its smooth interior surface, prevent "hot spots" and "carbon build-up" that are the prime causes of erratic tube life.

General Alloys Company is unique as a major producer of *both* castings and fabrications and therefore can recommend, without bias, the type of construction best suited for your needs.

For complete data, quotes, or engineering service contact the office nearest you . . . or write General Alloys Company, 401 West First Street, Boston 27, Massachusetts.

Lindberg Furnace Tube
General Alloys is a
Lindberg Licensee



All Fabricated

General Alloys Company also produces entirely cast, as well as entirely fabricated radiant tube assemblies, in all the heat resisting alloys for every purpose and in every size.

Ask about how our tube repair service can save you money!

GENERAL ALLOYS CO.

the only producer of both heat resisting castings and fabrications

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Vincent C. Leatherby
104 Fourth St.
Sharpsburg, Pa.

ST. LOUIS 16, Missouri
Associated Steel Mills, Inc.
P.O. Box 1986, Meramec Station

Circle 2080 on Page 48-B

1936. Hardness Testers

Bulletin CRS60 discusses complete line of motorized "Kentrall" hardness testers for accurate, rapid testing. *Torsion Balance Co.*

1937. Portable Testers

The *King Tester Corp.* will send literature on portable hardness testers which can test any size, shape or thickness of metal.

1938. Rockwell Testers

Catalog RT58 gives complete details on full line of "Wilson" hardness testing equipment. *Wilson Mechanical Instrument Div.*

1939. X-Ray Inspection

Lebanon Steel Foundry has published a bulletin on X-ray inspection of steel castings, which includes requirements for various classes of X-ray specifications.

1940. Control Instruments

4-p. catalog No. G-100 discusses electronic devices for measuring, indicating, recording and controlling dimensional change. *Measurement Control Devices.*

1941. Strain Indicator

Folder No. 360 describes "Model HW-1" portable strain indicator, which reduces strain gage setup time 30 to 50%. *Strainsert Co.*

1942. Gamma Radiography

Flyer from *Radionics Inc.* discusses "Model 60-1000 Gammatron" with a capacity of over 3000 curies of cobalt-60.

Production and Casting

1944. Shaft Seals

Cartriseal Corp. has 32-p. booklet illustrating complete line of rotating shaft seals — cartridge, grommet, boot, bellows, labyrinth, and "O"-Ring types.

1945. Foundry Binders

12-p. booklet on binders and sand additives will be sent by *Corn Products Div.* Properties and applications information included.

1946. Plaster Mold Casting

Well-illustrated 20-p. booklet presents facts on precision casting by plaster-mold technique. Process and product data included. *Ohio Precision Castings, Inc.*

1947. Block Insulation

12-p. catalog from *Johns Manville* presents data on "Superex" pipe and block insulation for service to 1900° F.

1948. "Notes on Strenes Metal"

Periodical contains information on ductile iron, gray iron, and "Strenes" metal castings and techniques. Data from *Advance Foundry Co.*

1949. Vacuum Pumps

Learn the reasons why you can get more pumping performance per dollar with "Series H Microvac" vacuum pumps. Information and free vacuum slide calculator from *F. J. Stokes Corp.*

1950. Precision Casting

56-p. booklet discusses "Shaw Process" precision ceramic casting in the foundry and toolmaking industries. *Shaw Process Development Corp.*

1951. Vacuum Induction Furnaces

Asea Electric Inc. will send folder on vacuum induction furnaces for melting steel — to improve fatigue strength and raise yield point.

1952. Master Alloys

WaiMet Alloys Co. will furnish information on "R.Met" alloy line — casting alloys, welding rod, master alloys, and forging billets.

1953. Anhydrous Ammonia

Data on anhydrous ammonia for N_2-H_2 protective atmospheres in annealing nickel alloys, electrical steels, Be-copper, Si-copper; also other hardening and brazing applications. *Allied Chemical Co.*

1954. "Vacuum Micronicle"

A periodical containing details on making products better with high-vacuum equipment — available from *NRC Equipment Corp.*

1955. Pure Ammonia

Armour Industrial Chemical Co. will furnish blueprints and engineering recommendations on cylinder and storage tank installations for 99.98% pure anhydrous ammonia.

1956. Electrolytic Manganese

Specification Sheet F20-151 gives data on "Elmang," a high-purity addition to steel, copper, or aluminum. *Union Carbide Metals Co.*

1957. Selective Plating

Brochure from *Sifco Metachemical, Inc.* on selective plating with the "Dalic" process for building up worn surfaces or for fitting bearings to close tolerances.

1958. Vacuum Furnaces

The *Kinney Vacuum Div.* will send information on high-vacuum furnaces for producing pure metals.

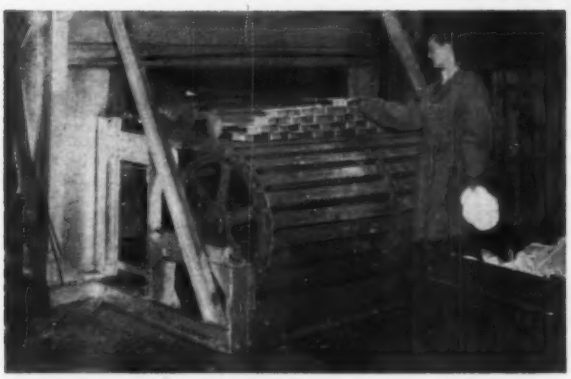
1959. Mixing Equipment

Bulletin B-521 presents information on "Lightnin" mixers for open and closed tanks. Size range from ¼ to 3 hp. *Mixing Equipment Co. Inc.*

1960. "CO_2" Cores

8-p. brochure on flash curing of foundry molds and cores with carbon dioxide explains the process and details the advantages. *Pure Carbonic Co.*

To request any item listed, circle appropriate number on Reply Card, p. 48B



Continuous Conveyor Type
ALUMINUM BILLET HEATING FURNACES

One of two furnaces installed at Harvey Aluminum, Torrance, California, heats 2500 pounds of aluminum billets per hour to 1000° F. Furnace is six feet wide and incorporates an automatically operated, direct gas fired recirculating heating system. Temperature uniformity guaranteed.

Ask for Bulletin HT-53.

THE **carl mayer** CORP.
20800 CENTER RIDGE RD. CLEVELAND 16, OHIO

OTHER PRODUCTS: Core & Mold Ovens • Rod Bakers • Paint and Ceramic Drying Ovens • Special Processing Equipment & Accessories

Circle 2081 on Page 48-B

ZIRCONIUM OXIDE CRUCIBLES

High Purity, High Temperature Melting

APPLICATIONS:
Nuclear Metals
High Temperature Alloys
Precious Metals
Special Glasses

FEATURES:
Non-wetting by Most Molten Metals
Chemically Inert
Excellent Thermal Shock Resistance
Low Thermal Conductivity
Quality Crucibles, Both Heavy Duty and Laboratory Types
Available in Standard Sizes from 6 ml to 50 lb.
Zirconium Oxides have a service temperature over 4000°F in vacuum, inert or oxidizing atmospheres. They can be used in induction, resistance or gas fired furnaces.

Write for prices and technical information.

Ram Mixes • Tubes • Wash Coating • Heat Shields • Brick
Pouring Nozzles • Custom Shapes • Crucibles
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ZIRCONIUM CORPORATION OF AMERICA
31501 Solon Road, Solon, Ohio
West Coast Rep. - W. P. Keith Co., Santa Fe Springs, Calif.

Circle 2082 on Page 48-B

Are your plant operations HAMPERED by a shortage of TRAINED METALS MEN?

The American Society for Metals, recognizing the urgent need for suitably trained metals men, established the Metals Engineering Institute in 1954. Since then the ASM Metals Engineering Institute, through its specialized home-study courses not available elsewhere, has trained thousands of men in fields which were, and still are, desperately short of skilled technicians. *The MEI can train those special men in your plant who have the ability and background but who lack the fundamental understanding of metals behavior and specific knowledge of the newest discoveries in metallurgy and related subjects.* Your plant can benefit from their new knowledge. Look over this list of beginning and advanced courses. Write today for specific information as it relates to your problem, or for our brochure explaining the MEI in-plant training program.

Courses Available Now:

Elements of Metallurgy
Heat Treatment of Steel
High Temperature Metals
Titanium
Copper, Brass and Bronze
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Metals for Nuclear Power
Stainless Steels
Electroplating and Metal Finishing
Gray Iron Foundry Practice
Oxy-Acetylene Welding
Steel Foundry Practice
Recovery of Lead and Zinc
Steel Plant Processes
Ferrous Metallurgy
Corrosion
Principles of Machining
Fundamentals of Welding and Joining
Principles of Heat Treating

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1961. Nodular Iron

8-p. Brochure No. 47 from *Meehanite Metal Corp.* gives specifications and applications of nodular iron.

1962. Sintering Furnaces

Bulletin 4-25 from *Consolidated Vacuum Corp.* discusses induction furnaces for sintering in vacuum up to 3000° C.

1963. Fire Brick

"HW23LI" insulated fire brick is resistant to industrial gases found in controlled atmosphere furnaces. Specific information available from *Harbison-Walker Refractories Co.*

1964. Wire Cloth

Ninety-four page catalog from *Cambridge Wire Cloth Co.* describes complete line of industrial wire cloths.

1965. Industrial Concrete

Universal Atlas Cement Div. will send more information on industrial concretes for protecting blast furnace "hot spots".

1966. Manganese Additions

Carbon, silicon, and other impurities never get to the melt when you use pure "electromanganese additions". Bulletin 201 from *Foote Mineral Co.*

1967. Platinum Products

Catalog No. 5 from *J. Bishop & Co.* describes complete line of platinum products and chemicals.

1968. "No-Bake" Cores

16-p. brochure presents information on "Kold-Kure" no-bake process for preparation of sand molds and cores used in iron and steel casting operations. *G. E. Smith, Inc.*

1969. Vacuum Coating

28-p. Bulletin 2-2 from *Consolidated Vacuum Corp.* describes vacuum coating applications and equipment. Both metals and nonmetals can be coated without dependence on electrical conductivity.

1970. Cleaning of Castings

Dual purpose core knock-out and blast cleaning equipment for the foundry is discussed in brochure issued by *Wheelabrator Corp.*

1971. Exothermic Ferrocolumbium

Folder details advantages of "Vancoram Thermocol", an exothermic ferrocolumbium addition to carbon and stainless steels and high-temperature alloys. *Vanadium Corp. of America.*

Parts, Forms, Shapes

1972. Press Parts

Bulletin EP11 presents information on precision parts for extrusion presses. *Specialty Steels, Inc.*

1974. Aircraft Fastener Standards

Rapid identification of 160 standard aerospace fasteners — by configuration; by NAS, AN, MS specification number; and by generic name — is provided in a 10-p. reference listing published by *Standard Pressed Steel Co.*

1975. "Powder Metallurgy"

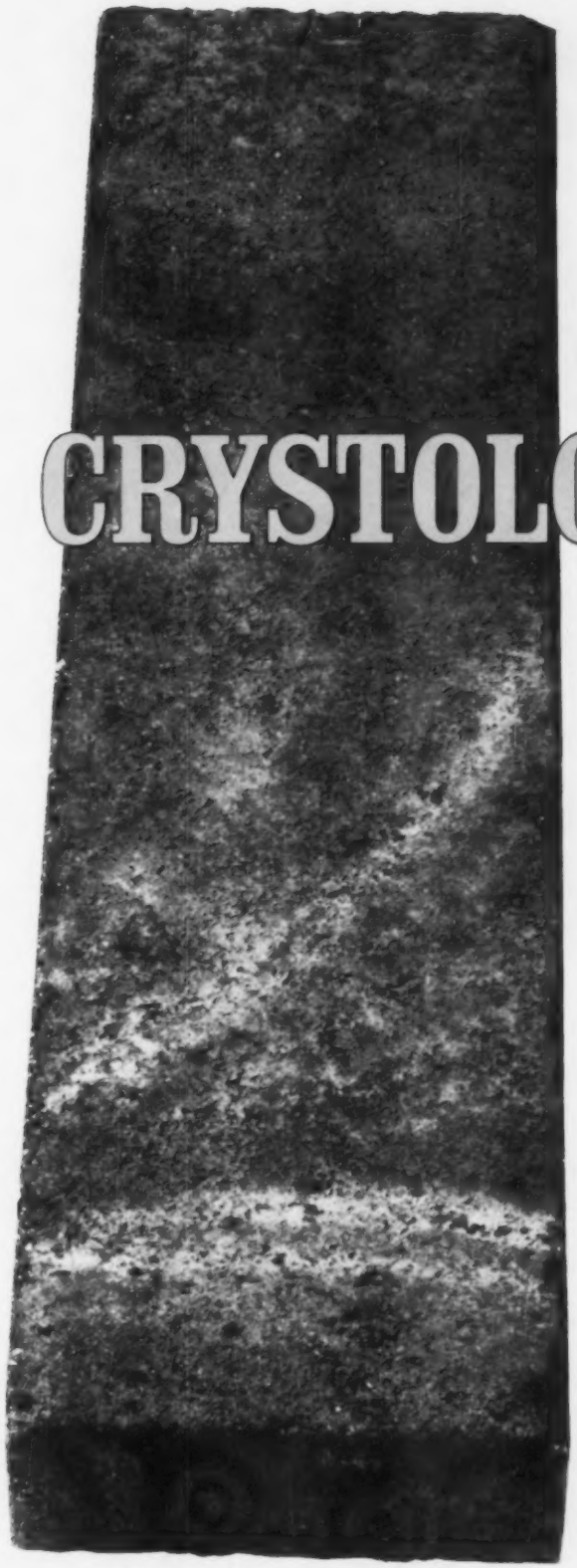
Quarterly publication of the *Metal Powder Industries Federation* (spring-summer 1960) features case histories of electrical applications for powder metallurgy parts.

1976. Steel Belts

Folder from *Prab Conveyors, Inc.* presents advantages of "Multi-Flex" flat top steel belts which have the flexibility of rubber belts, but have positive drive and wheeled-track construction.

1977. Contour Rolled Stock

D. E. Makepeace Div. will send literature on contour rolled stock held to dimensions as close as 0.001 in. Can be made from any cold-workable material.



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CRYSTOLON* "63"

Now, the best-performing silicon carbide refractory is available at a realistic price! Brand-new CRYSTOLON "63" permits the use of a cost-saving nitride-bonded silicon carbide refractory for hundreds of applications.

Produced by an exclusive Norton process, CRYSTOLON "63" silicon carbide provides all the superior properties of nitride-bonded silicon carbide at a *new low cost!* It has high thermal conductivity, excellent heat shock and wear resistance, and good resistance to most corrosive liquids. In extensive tests, it not only showed excellent resistance to "wetting" by molten non-ferrous metals (aluminum, magnesium, zinc, lead and others) but also to fused salts, such as cryolite!

CRYSTOLON "63" refractories can well mean a vast improvement in many of today's metal melting and transfer operations . . . new efficiency and economy *throughout* operations such as *yours*. Get complete details now! Write NORTON COMPANY, Refractories Division, 330 New Bond Street, Worcester 6, Massachusetts.

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Steels and irons with "vitality" to spare...*start with Vancoram Ferrovanadium*

It takes only a small amount of Vancoram Ferrovanadium to impart *extra* strength and *extra* durability to a wide variety of steels and irons. Ferrovanadium controls grain size, improves hardenability, and is especially useful in tool and die steels because it provides excellent cutting and wearing characteristics. Constructional steels, deep-drawing steels, and cast and forged steels also benefit from Vancoram Ferrovanadium additions.

In cast irons, Ferrovanadium promotes formation of small, uniform graphite flakes, thus increasing tensile strength. Furthermore, the presence of vanadium carbide improves resistance to structural changes at elevated temperatures. Write for literature, or call your nearest VCA District Office. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. • Chicago • Cleveland • Detroit • Pittsburgh.

Vancoram Products are also distributed by: Pacific Metals Co., Ltd. • Steel Sales Corporation • J. M. Tull Metal and Supply Co., Inc. • Whitehead Metals, Inc. • Williams and Company, Inc.

VANADIUM
CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

VANCORAM

Circle 2084 on Page 48-S

The American Society for Metals and Metal Progress serve 32,000 member-readers in 11 major areas of the metals industry.

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS: Alloy, Carbon, Free Machining, Stainless Steels, Hot and Cold Finished Bars.

NONFERROUS METALS: Aluminum, Beryllium, Brass, Bronze, Columbium, Copper, Lead, Magnesium, Molybdenum, Monel, Nickel, Rare Earths, Tantalum, Titanium, Tungsten, Zinc, Zirconium.

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PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS: Castings (Malleable, Gray Iron, Steel, Nonferrous), Forgings, Extrusions, Powder Metal Parts, Springs, Stampings, Tubing, Weldments, Wire.

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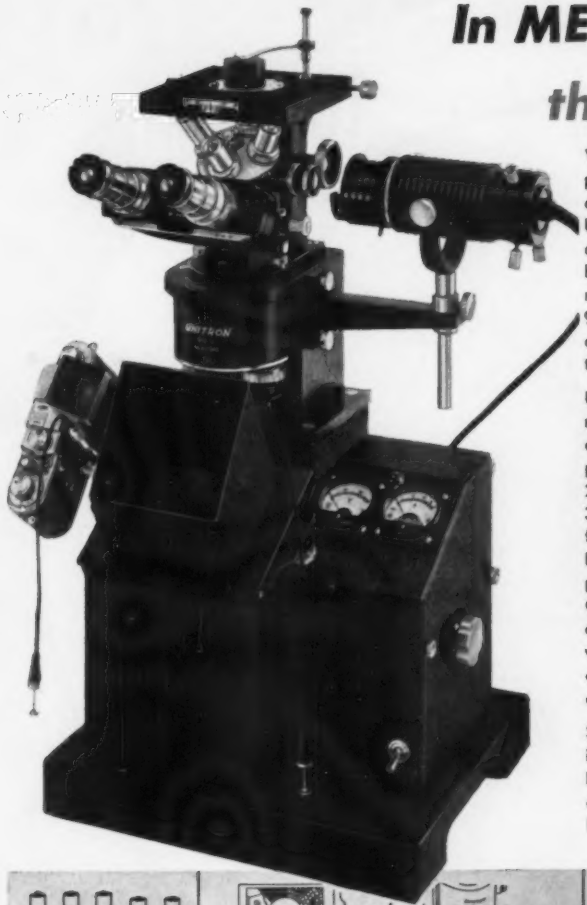
In METALLOGRAPHS...

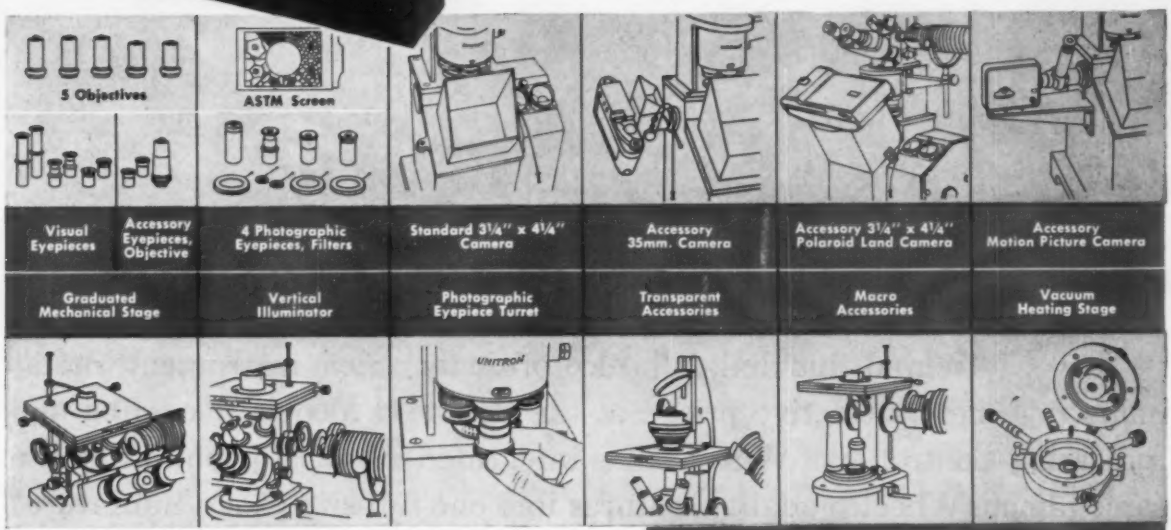
the trend is to UNITRON!



What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



FREE 10 DAY TRIAL

UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379 f.o.b. Boston

Monocular Model U-11 **$1195**

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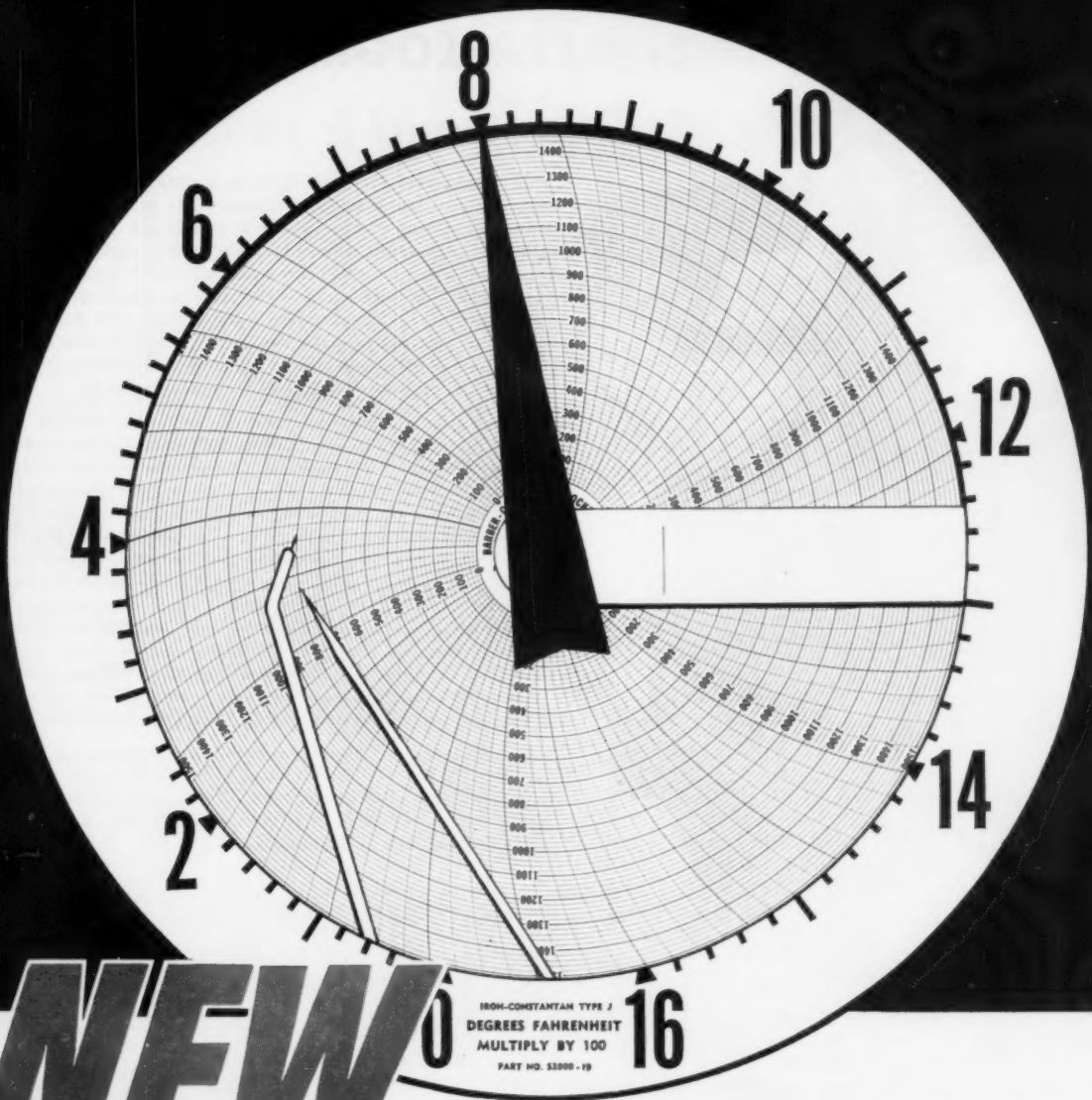
THE TREND IS TO UNITRON

Circle 2085 on Page 48-B



NEW

WHEELCO "DOUBLE-O"

Behind this dial, Wheelco presents a *new* instrument line at industry's most attractive price . . . the Double-O Models Recording and Indicating Controllers. Wheelco has integrated the most popular and the same famous Wheelco quality features into one full-size (not a miniature) electronic potentiometer controller line. And now, a volume production savings is passed on to you. Write today for complete details.

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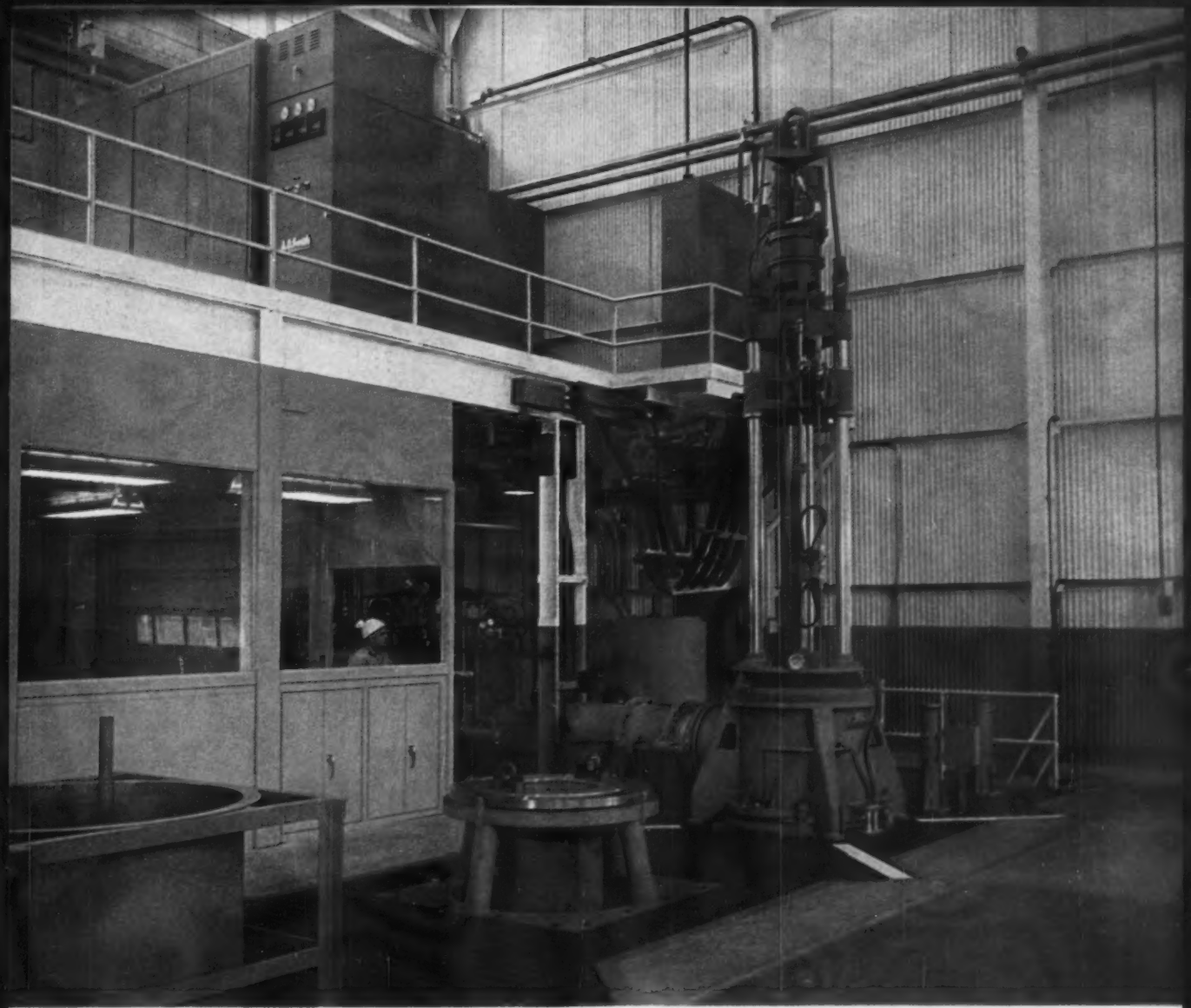

SPECIAL QUALITY STEELS AVAILABLE AT STANDARD

One of the largest vacuum arc remelt furnaces in the country—the first of four to be installed—is now in operation at Standard Steel Works Division of Baldwin-Lima-Hamilton Corp. This new facility, together with electric melting furnace and vacuum degassing equipment acquired recently, now makes it possible for Standard to deliver "laboratory-quality" steels in production quantity.

Standard is now capable of producing vacuum remelt quality ingots, up to 30-inch diameter, in all of the super-strength steels and special alloys requiring exceptional quality. Standard continues to offer superior service and superior materials to American industry. We especially welcome forging and ring inquiries for tools, missiles, turbines, bearings and similar applications for super-strength, heat-resistant, corrosion-resistant and other special alloys.

Standard Steel Works Division
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Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes

BALDWIN BLH LIMA-HAMILTON

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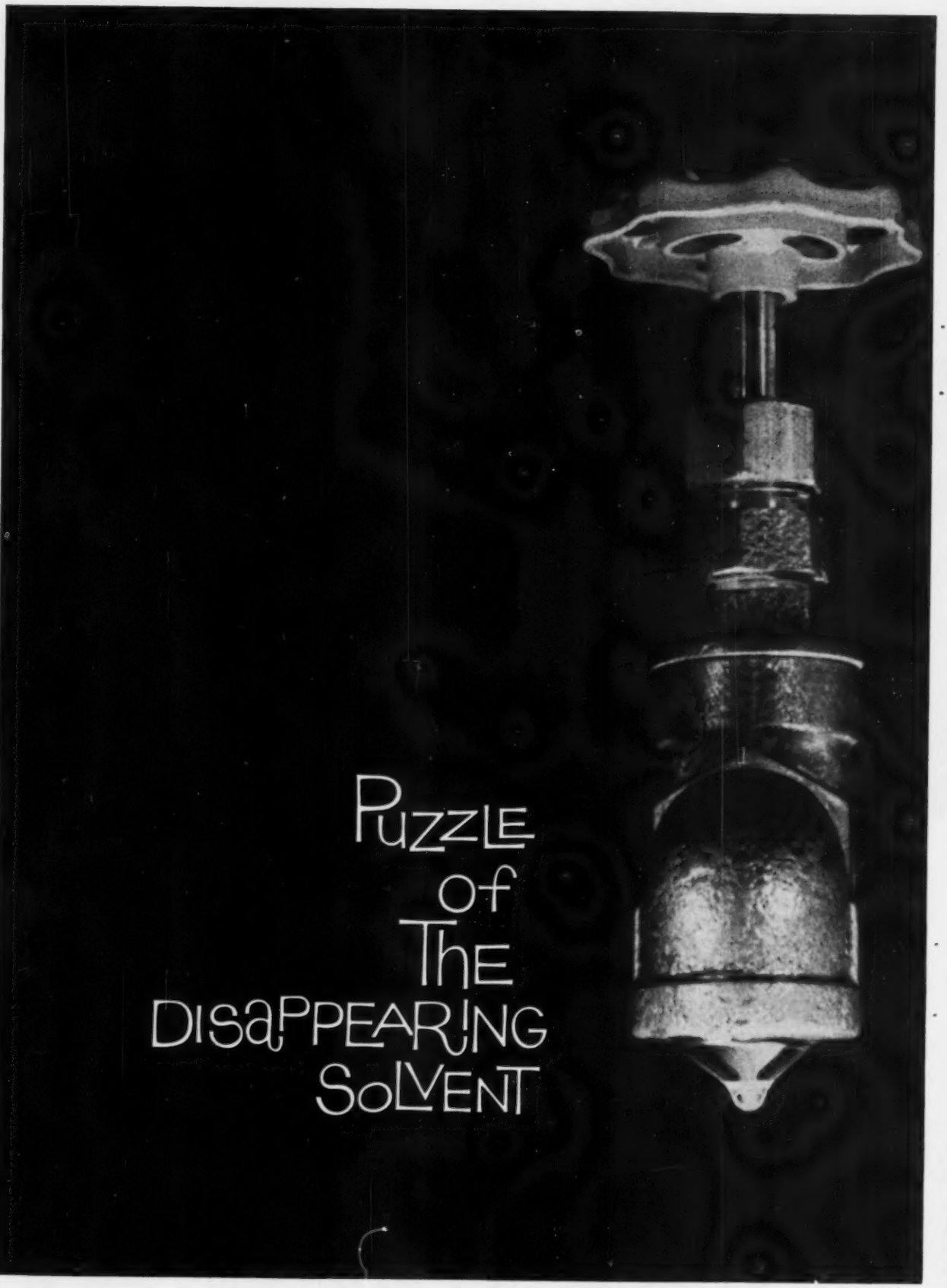
PUZZLE
of
THE
DISAPPEARING
SOLVENT

OR how to degrease more parts per dollar of cleaning cost

Every time they needed more vapor-degreasing solvent, the drum was empty, it seemed.

At first it didn't bother them much. Then, suddenly, they realized what was happening to their degreasing costs.

The solvent wasn't lasting as long as it should between bath cleanouts. That's why they had to use so much of it. Worst of all, every time a bath went sour they had to pull the degreaser off the line. That's where the real expense was lurking: in slowed-up production.

PSP TO THE RESCUE They solved the puzzle—with a degreasing solvent that can't wear out prematurely. It has permanent staying power—psp—because it's protected by a stabilizer that doesn't get used up during degreasing.

You stand a good chance of getting lower metal-cleaning cost with this solvent, too. It's called Nialk TRICHLOR. You don't have to add fresh stabilizer to it. Even when you distill the solvent, it remains stable. Even the vapor is stabilized. And you use less solvent, because less goes down the drain in unnecessary cleanouts.

Interested in finding out what you can save with this better trichlorethylene? Your Nialk TRICHLOR distributor can give you swift service on the quantity you need. Call him today.

NEW 36-PAGE BULLETIN explains fully how you get more and better vapor degreasing for your money with Nialk TRICHLOR. Shows basic types of vapor degreasers. Discusses cycles, operating procedures, stabilizers, causes of solvent contamination, solvent recovery, trouble shooting. Ask your distributor for a copy, or write us.

Nialk® TRICHLOR, a product of

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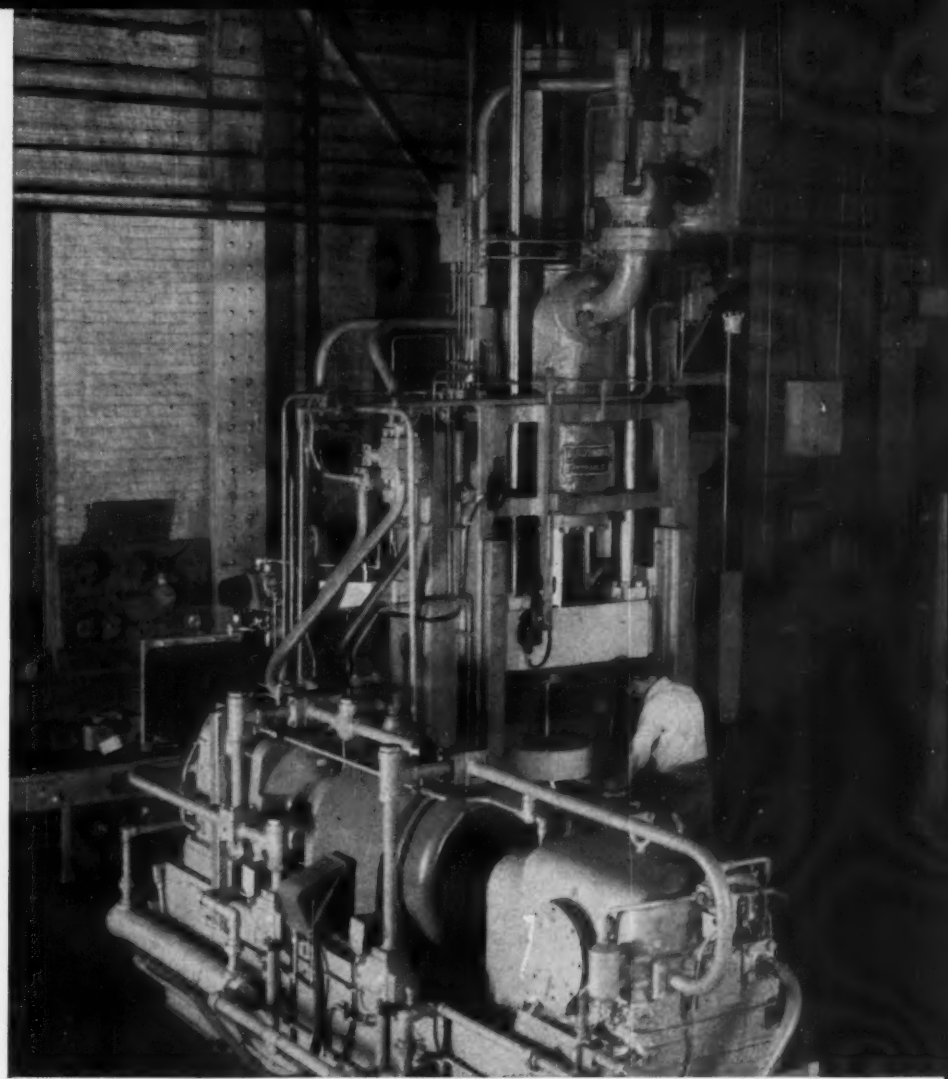
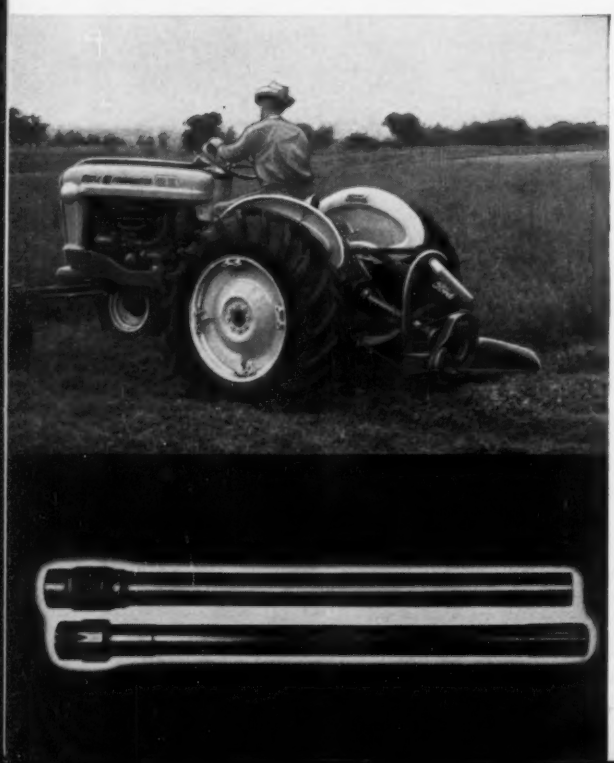
HOOKER CHEMICALS PLASTICS

Circle 2088 on Page 48-B

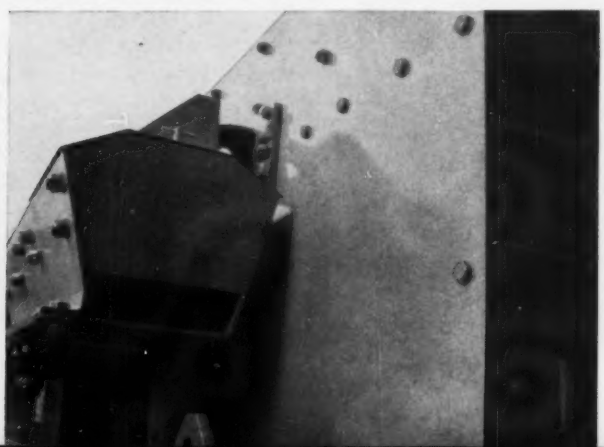


This 500-ton hydraulically operated press built by Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa., and featuring Republic ELECTRUNITE Hydraulic Fluid Line Tubing, is used by a leading research center for deep drawing, extruding, or planishing metals.



REPUBLIC DIE-FORM CUTS PRODUCTION COSTS. Ford Tractor Power Take-Off Counter-Shaft costs less to produce using a Republic Die-Form Blank, as compared to previous materials. Because Republic Die-Form Blanks closely approximate the completed part, they minimize required machining and reduce handling costs. In addition, the nature of the Die-Form Process improves machinability of any given analysis, permitting further savings through use of higher speeds and feeds. Photo below shows a Die-Form Blank and the completed shaft as featured in the Ford Tractor. Write for Die-Form Folder ADV-746.

REPUBLIC CAP SCREWS PROTECT SHAKER SCREEN PERFORMANCE. Sorting and sizing ton after ton of jolting, jarring, abrasive material is all in a day's work for Ty-Rock Vibrating Screens, built by The W. S. Tyler Company, Cleveland, Ohio. Satisfactory performance under these brutal conditions not only requires design and manufacturing skill, but a thorough knowledge of materials. Maximum performance under all operating conditions is typical of Republic's complete line of top-quality Cap Screws. Send coupon for data.



Stubborn resistance to fatigue...

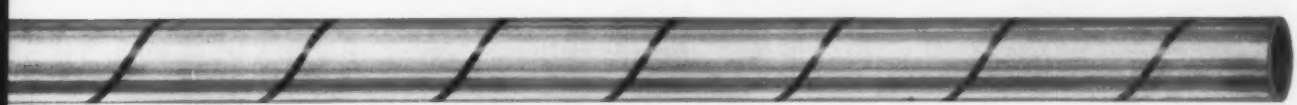
REPUBLIC ELECTRUNITE HYDRAULIC FLUID LINE TUBING

Machine tool builders and operators depend upon Republic ELECTRUNITE® Hydraulic Fluid Line Tubing for stubborn resistance to fatigue. Reason is the *consistent uniformity of concentricity* and mechanical properties of ELECTRUNITE welded steel tubing—characteristics that make this tube better able to withstand the vibrations of rapid multiple cycling.

This uniform concentricity—inherent in the ELECTRUNITE process—coupled with uniform heat treatment, insures uniform flaring characteristics. Uniform ductility assures easy bending. Both mean savings in original and in replacement installations.

You can recognize this best of all hydraulic line tubing by the blue spiral marking stenciled end-to-end on every length. It is your assurance of genuine ELECTRUNITE quality. The spiral marked tube is available in all sizes shown in JIC Standards, and is produced in a wider size range to Specification HL-1, which meets all JIC Standards test requirements.

Get all the facts. Discover how Republic ELECTRUNITE Hydraulic Fluid Line Tubing can substantially reduce maintenance costs in the most complicated installations. Call your Republic representative, or send coupon for additional information.



REPUBLIC WEDGE-LOCK PARTS STORAGE UNITS are easy to load and unload from either side. And, the heavier the load, the tighter the grip, because patented Wedge-Lock construction includes a post that will not buckle, a concealed sway-proof joint, and a reinforced shelf that does not sag. Unlimited shelf arrangements. Capable of exceptionally high stacking. Republic Storage Engineering specialists will help you plan. Call your Republic representative today.

Circle 2089 on Page 48-B

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
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1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on the following products:

- ☐ Republic ELECTRUNITE Hydraulic Fluid Line Tubing
- ☐ Republic Die-Form—Folder ADV-746
- ☐ Republic Cap Screws ☐ Wedge-Lock Storage Units

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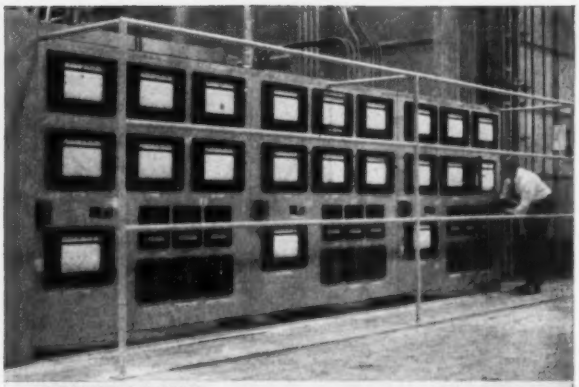
SOAKING. These Bristol Dynamaster® instruments monitor soaking pit operation in new, multi-million-dollar aluminum fabricating plant of Anaconda Aluminum Company at Terre Haute, Indiana. Staff engineer analyzes record.



ANNEALING. Dynamaster® instruments here control and record annealing furnace temperatures in new Anaconda Aluminum plant. Over 11½ acres under one roof, the new plant produces aluminum sheets, extrusions, tubes and ingots.

HEAT TREATING. Anaconda staff engineer checks temperature records, produced by Bristol Dynamaster instruments, for vertical extrusion heat-treating tower, part of which is shown at left.

AGING. Dynamaster instrument panel at left controls and records temperatures in aging furnaces in new Anaconda Aluminum Company plant. Furnace operator at right is moving rack car into furnace.

BRISTOL INSTRUMENTS FOR THE METAL INDUSTRY

The key to higher quality, more uniform production, greater efficiency

Bristol offers pyrometers for every requirement: Electronic potentiometers (including miniature models), millivoltmeter and radiation types... for furnaces, ovens... every type of heating equipment, every kind of fuel.

Bristol Dynamaster® electronic potentiometer pyrometers, service-tested and proved in thousands of industrial plant installations, fully measure up to the requirements of today's most advanced steel and metal-working plants. Check these modern features:

1. Continuous standardization—eliminates usual standardizing mechanism and dry cell... no interruption to control.

2. Simple, modular design—few moving parts.

3. Easy to use and service—minimum maintenance.

4. Rugged construction—continued accuracy and reliability under tough conditions.

Write for complete data—and remember, Bristol markets a complete line of pyrometer accessories available for fast delivery to keep your plant in operation. The Bristol Company, **106** Bristol Road, Waterbury 20, Conn. *®T. M. Reg. U. S. Pat. Off.*

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

METALGRAMS

UNION CARBIDE METALS

. . . news about "Electromet" ferroalloys and metals

NOVEMBER, 1960

AN EFFICIENT BLOCK -- Why is silicomanganese the most popular blocking alloy in the steel industry today? It dissolves 50 per cent faster than separate silicon and manganese additions, giving faster blocks and shorter blocking times. Its low-carbon content allows higher tapping carbons, reducing furnace time and also aiding steel cleanliness. Since silicomanganese is a more powerful deoxidizer than straight silicon blocks, it gives tighter blocks that last longer. Finally, silicomanganese provides low-cost silicon and manganese, reducing blocking costs to a minimum.

* * *

BETTER CONTROL, TOO! -- Results of hundreds of open-hearth production heats show that a silicomanganese block gives better control of carbon content and alloy additions. Off-grade heats for carbon and manganese have been shown to be lowest for silicomanganese compared to a pig ferrosilicon or a 50 per cent ferrosilicon block. Also, silicomanganese gave a higher manganese recovery than other blocks when all the manganese was added to the furnace. For details, write for the article, "Silicomanganese Improves Blocking Performance," in the Fall 1960 issue of UNION CARBIDE METALS REVIEW.

* * *

LOWER COSTS FOR STAINLESS STEEL -- Another manganese-silicon alloy -- ferromanganese-silicon -- is saving stainless steel producers thousands of dollars per year. Used for slag reduction and manganese additions, ferromanganese-silicon is replacing other low-carbon manganese sources. Savings per ton: $0.75 to $1.75 for type 300 stainless grades and $4 to $9 for type 200 grades. Some stainless producers have also found that ferromanganese-silicon produces cleaner steels. Write for F-20,093 for further information.

* * *

BUILDING BIGGER MARKETS -- "Your man's practically a member of my staff," a president of a steel firm said of one of UCM's market development specialists. These men work with steel producers to develop new markets and expand old ones. Primarily, they promote the use of stainless steel and titanium (including castings) in transportation, architecture, process industries, and consumer goods. More details can be obtained by writing for the article, "Men, Metals, and Markets," in the Spring 1960 issue of UNION CARBIDE METALS REVIEW.

* * *

PRODUCTS WITH A SPLIT PERSONALITY -- Several "Electromet" alloys and metals are used in both metals and chemicals. Silicon metal -- an important alloy in aluminum and copper -- is a key raw material for silicones. Vanadium oxide -- used in tool and constructional steels -- is a catalyst in the production of adipic acid, sulfuric acid, maleic anhydride, and phthalic anhydride. It also gives special colors to glass and ceramics. Finally, "Elmang" electrolytic manganese -- high-purity manganese for stainless steel, deep-drawing steels, copper and aluminum -- is a catalyst for adipic, terephthalic, and acetic acids. Write for the article, "Products with a Split Personality," in the Spring issue of UNION CARBIDE METALS REVIEW.

* * *

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 270 Park Ave., New York 17, N. Y. In Canada: Union Carbide Canada Ltd., Toronto.

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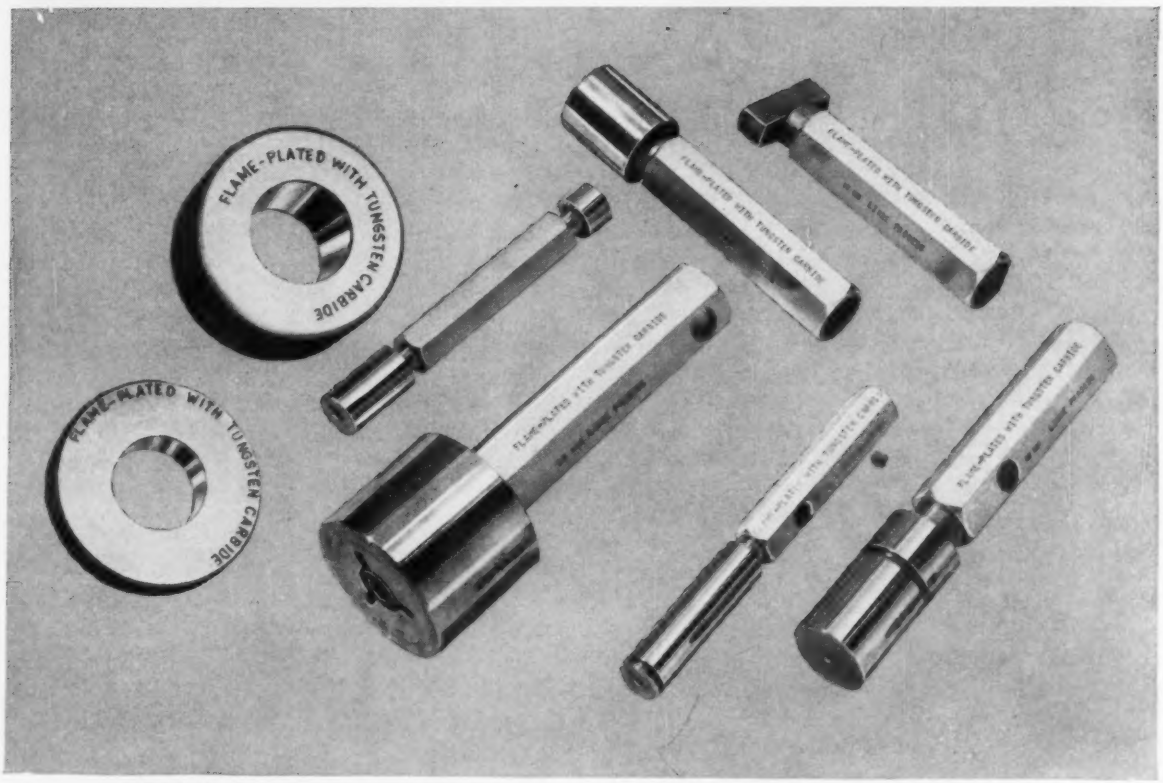
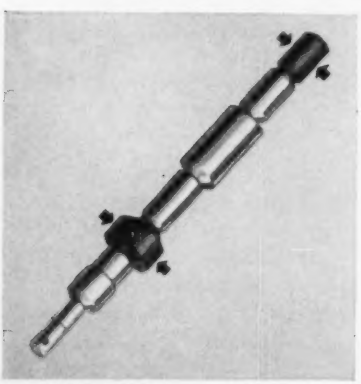
PRECISION PARTS GET TODAY'S

LINDE's FLAME-



GAGES—Superior wear resistance and other unique cost-saving advantages are exhibited by plug, ring, air, and specialty gages treated by LINDE's Flame-Plating. For example, Flame-Plated plug gages outwear solid carbide plug gages 3-to-1, and hard chrome-plated gages 20-to-1.

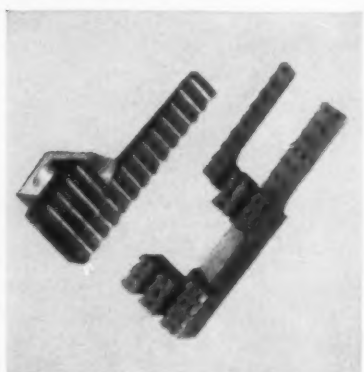


AIRCRAFT VALVES

Bearing surfaces of hot air valves used in the bleed air system of Lockheed's F-104A Starfighter must meet extreme conditions of wear and abrasion, also conditions of high unit loading and temperature extremes. Flame-Plating these surfaces with tungsten carbide solves the problem.

ALUMINUM ROCKER ARMS

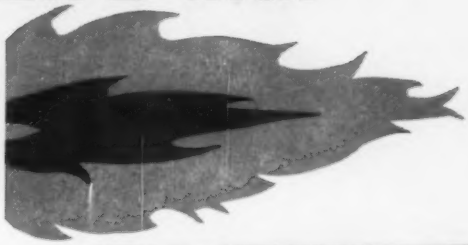
One side of the "fin" of this important item in an aircraft engine heater mechanism actuates a lever and is subjected to severe wear. Before Flame-Plating, it lasted from 100 to 300 hours. Coating the wearing surface with tungsten carbide boosted service life to more than 1000 hours.



SEWING MACHINE FEED DOGS

LINDE's Flame-Plating has increased by more than six times the service life of the movable, serrated part that pushes material through the sewing machine. In this application, a .002-in. coating of tungsten carbide in as-coated condition provides both long wear and dependable gripping.

LONGEST SERVICE LIFE with PLATING



Gages and other components achieve remarkable resistance to wear when coated with tungsten carbide and other materials by LINDE's 6,000-degree, supersonic "weld-on" process . . .

NOW—many of the profit-consuming problems of metal wear and machine down-time have been eliminated.

With LINDE's Flame-Plating, gages, spindles, bushings, seals, mandrils, dies, core rods and other precision parts and components retain their precision and close tolerances for the *longest* period of time—under the toughest conditions of abrasion, erosion, corrosion, and high-temperature wear.

LINDE's exclusive service coats base metals with particles of ultra-hard materials, such as tungsten carbide and aluminum oxide—heated to plasticity by 6,000 degrees F. inside the Flame-Plating gun and then successively "fired" at 2,500 fps at the "target area."

The result is a tenacious, "welded-on" coating of approximately 125 microinches rms, which can be finished to the desired microinches rms.

NO WARPAGE—NO METALLURGICAL CHANGES

Despite the 6,000-degree temperature within the Flame-Plating gun, the temperature of the precision part or product being coated remains below 250 degrees F. This feature eliminates distortion and changes in the properties of base metals. Other features include low coefficient of friction and porosity of less than 1 per cent.

Wherever *continuing* precision and *optimum* wear are important factors, LINDE's revolutionary Flame-Plating gives amazingly longer service life . . . reduces production rejects . . . increases salvage value.

Find out how this coating service offered by the Linde Company can save on operating costs, make a good product even better, and improve over-all reliability. LINDE will provide a complete engineering analysis. List your possible applications in the coupon on the right and mail today for complete information.

LINDE COMPANY
Division of Union Carbide Corporation

LINDE and UNION CARBIDE
are trade-marks of Union Carbide Corporation.

UNION CARBIDE

TYPICAL FLAME-PLATING APPLICATIONS

BEARINGS – sleeve, roller, gas
BLADES – aircraft turbine; doctor blades for papermaking
BLOCKS – anvil
BUSHINGS – ball piston pump
CHUCKS – seaming
CUTLERY – household
CUTTING, INDUSTRIAL – rubber, plastic, skiving knives, foods, paper, slitter knives, chipper knives, discontinuous chip-abrasive materials
DIES, TOOLING – cold-forming; coring punches, core rods, sizing punches, capstans
DOGS – sewing machine feed; gripping dogs
DRILLS – paper, acoustical tile, twist
GAGES – plug, ring, air
GUIDES – wire, textile, machine
HYDRAULICS – pistons, liners, valve plates, wobble plates, metering valves, servo valves, slippers
MANDRILS – wire-forming
PARTS – sintered
PISTON RINGS
PLATES – valve, wear
SEALS – turbine engine, pump
SURGICAL – needle holders and shears
VALVES – aircraft

MP-11

Linde Company, Flame-Plating
270 Park Avenue
New York 17, New York

I am interested in Flame-Plating for the following application(s):

_____

_____

_____

NAME_____ TITLE_____

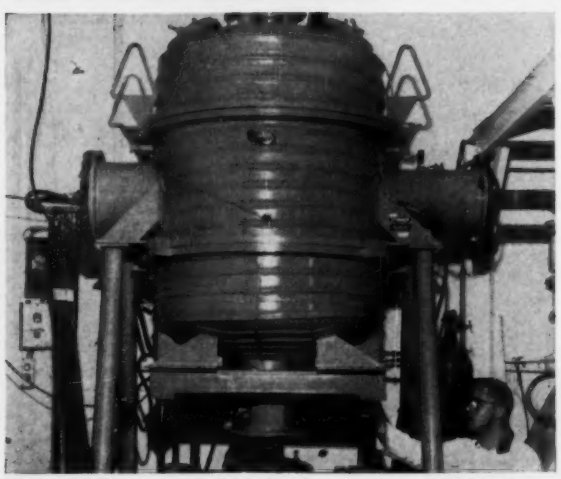
COMPANY_____

ADDRESS_____

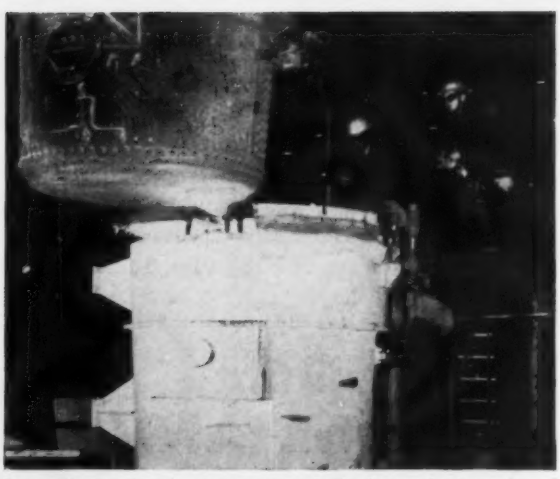
CITY_____ ZONE___ STATE____

Circle 2092 on Page 48-B

One of the largest cold-wall vacuum heat treating furnaces ever built, capable of operations at 2250°F. was supplied by Stokes to Convair (Astronautics) Division of General Dynamics Corporation. The huge furnace will be used in brazing and heat treating the high alloy steels used in the production of the Atlas ICBM. It has a vacuum chamber 12 feet long and 9 feet in diameter.



Uranium melting on a production basis is accomplished by this Stokes induction melting furnace at Atomics International. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of cast materials.



First acid open hearth, vacuum stream ladle degassed, air-pouring of multiple ingots in the U. S. took place at Ohio Steel Foundry in Stokes equipment. Results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

CUSTOM APPROACH TO YOUR UNACCUSTOMED PROBLEMS...

a Stokes specialty in vacuum metallurgy

Staffed and equipped to undertake projects which contain unusual problems, Stokes offers the most comprehensive background of vacuum metallurgical experience and know-how available today. Stokes is geared to tackle even the most complex assignments . . . assignments for which the application of high vacuum is the only practical solution.

New vacuum methods and techniques—first introduced by Stokes—are helping to capitalize on more and more opportunities in the metallurgical field. These advances are helping industry break through old bottlenecks . . . while reducing operating costs. In the nuclear field, for example, Stokes equipment has been used to develop new methods for plutonium melting and casting, uranium melting on a production basis, and radioactive materials handling. In metal refining, hydrogen embrittlement is being reduced with the aid of Stokes vacuum stream degassing equipment. In melting, heat treating, sintering and brazing . . . and in vacuum metallizing of thin and heavy coatings for decorative and functional applications . . . Stokes leads the field in new developments.

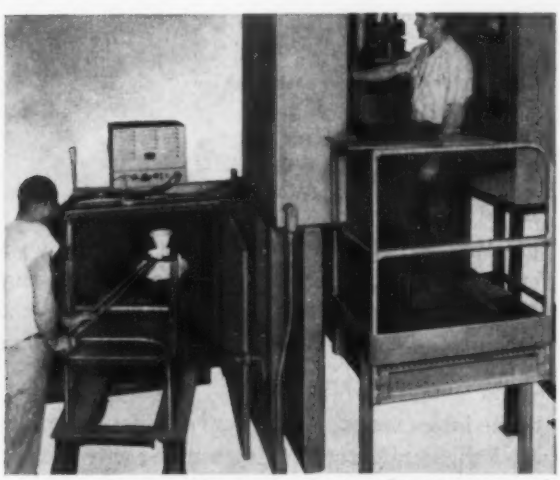
Advantages that take the guesswork out of operations . . . and brighten profit potential are inherent in Stokes equipment. For instance, we have demonstrated our capability in supplying a complete turnkey installation—erected, tested and delivered in operation. And our stocked components mean faster delivery, fewer costly holdups. All Stokes systems are offered complete . . . Stokes is your single source of responsibility for performance and reliability both before and after the sale.

Let Stokes put its unique experience and facilities to work on your problems. Our Engineering Advisory Service will help you in planning and designing an installation that will best serve your exact requirements. And whatever those needs are, the inherent flexibility of Stokes design concepts is assurance that they will be satisfied.

STOKES

Vacuum Metallurgical Division

F. J. STOKES CORPORATION • 5500 TABOR ROAD, PHILADELPHIA 20, PA.



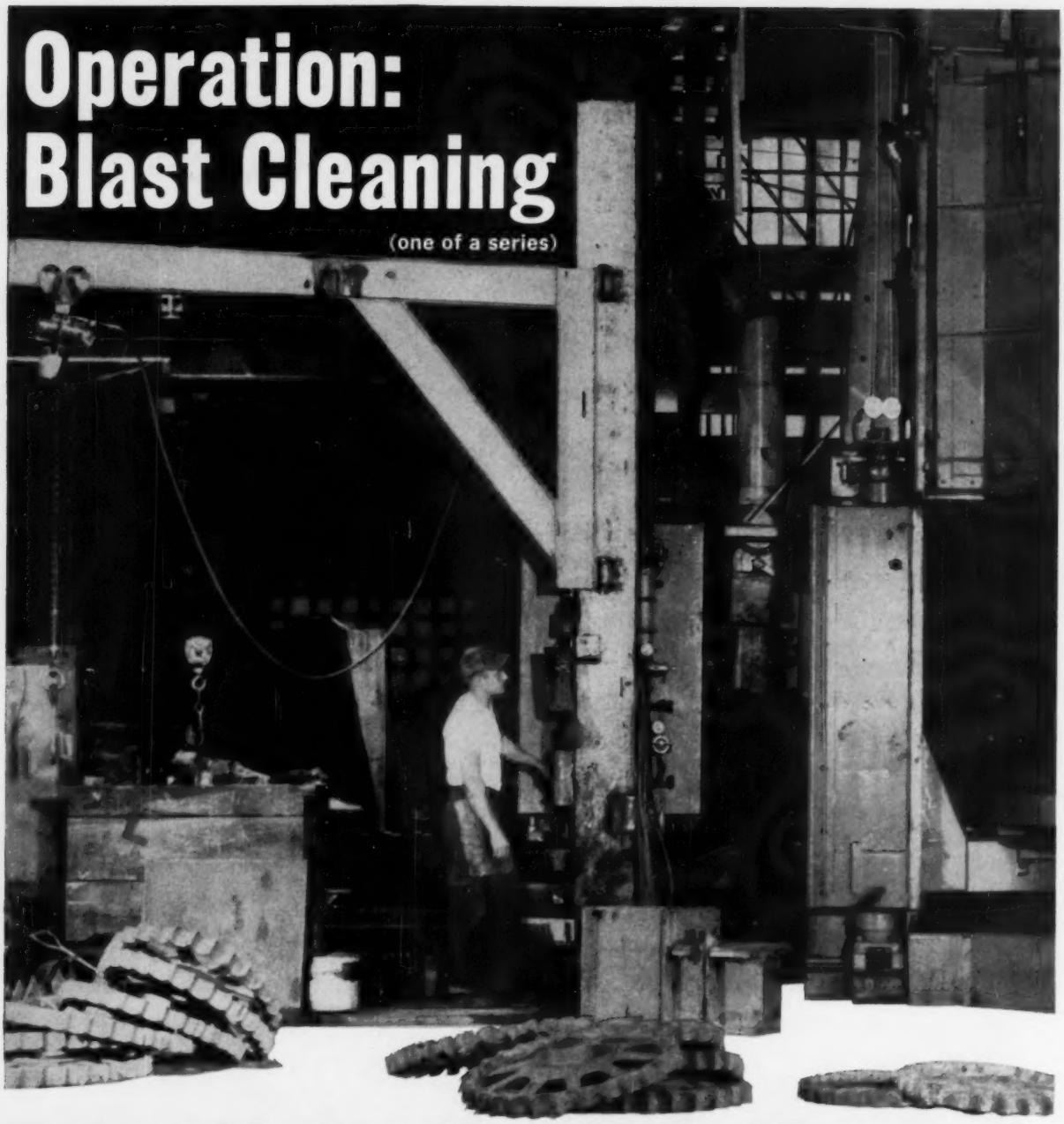
At Misco Precision Casting Co., semi-continuous vacuum melting and casting are being accomplished in two Stokes induction furnaces. Successive charges of the metal are introduced into the vacuum chamber from the outside, loaded into the crucible, melted, poured, and the cast pieces (in their molds) removed from the chamber . . . without breaking the vacuum.

Vacuum equipment capable of brazing panels in excess of 50 sq. ft. is being used in pilot operation by Grumman Aircraft Engineering Corporation to fabricate structures for the "Eagle" air-to-air missile. The Stokes equipment employs a new procedure which eliminates expensive and time-consuming welded "envelopes" to enclose the work. And high vacuum eliminates the need for costly inert gas.

Circle 2093 on Page 48-B

Operation: Blast Cleaning

(one of a series)



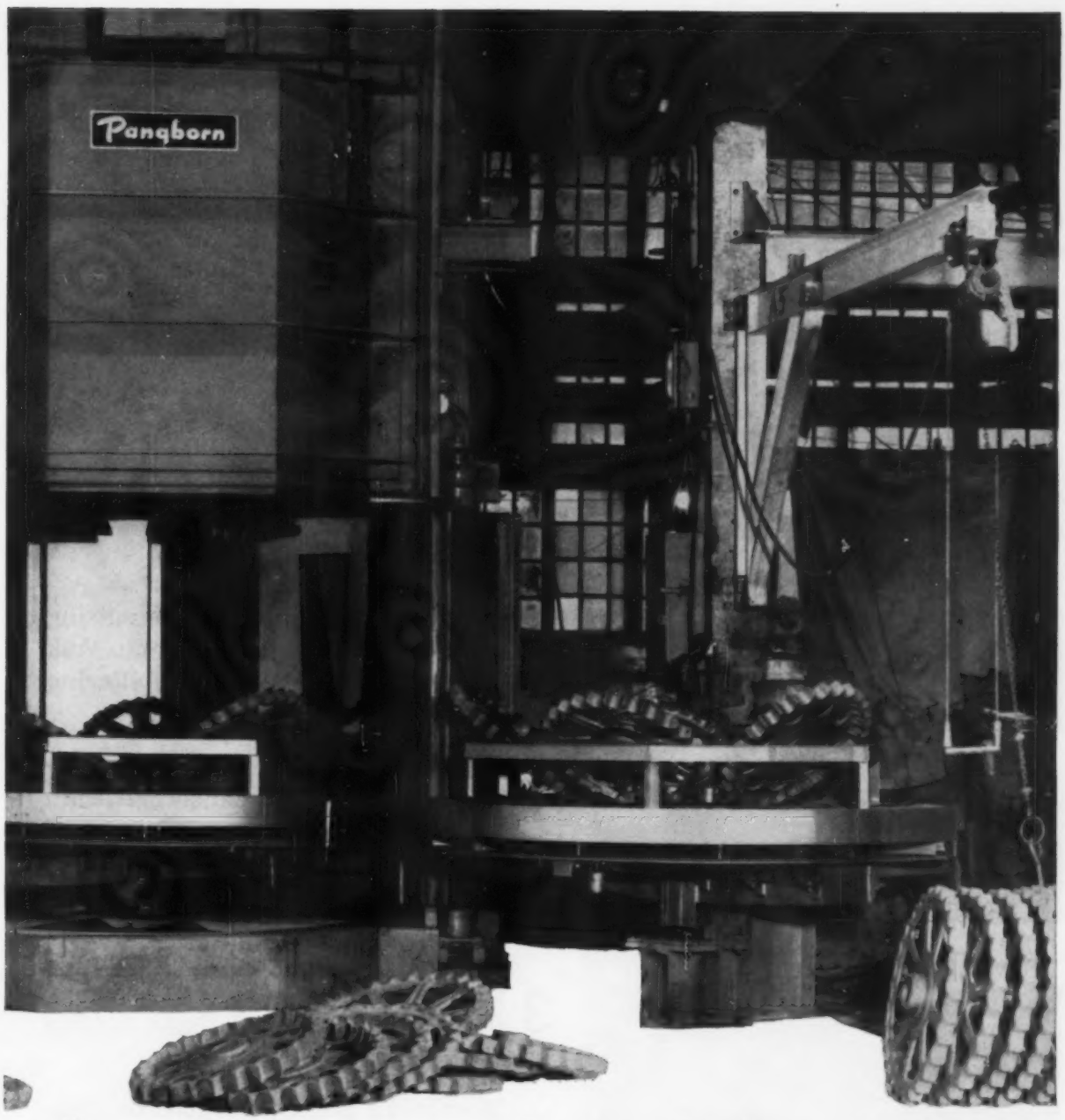
Twin-table Rotoblast hurls 50 tons of

Here's why the Pangborn Rotoblast "LM" Table Room doubled the capacity of the cleaning department at Harrison Steel Castings Co., Attica, Ind.

Inside the "LM" Table Room two Rotoblast Wheels throw 100,000 lbs. of abrasive at the castings every hour. This is blast power at its best. The abrasive hurled in a pattern designed to clean thoroughly every spot on every casting, even on bulky pieces up to 8′ in diameter.

During the cleaning process, castings rest on a rotating work table which increases the efficiency of the blast pattern. While one table is in the machine, its twin is being loaded outside. This makes for quick, continuous operation.

The tables are accessible from all sides (an exclusive Pangborn feature). They handle easily and can be pushed by hand with little effort. In the loading process, their weight is supported by a stationary



shot per hour... cleans twice as fast!

floor pedestal—rather than door hinges—for long life and trouble-free operation.

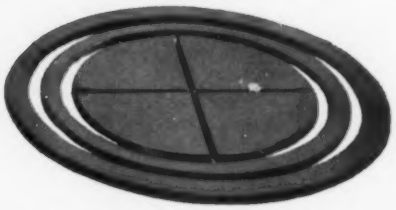
If the Pangborn "LM" Table Room has doubled the capacity of Harrison's cleaning department, it can do the same at your plant. For complete information write to: PANGBORN CORPORATION, 1800 Pangborn Boulevard, Hagerstown, Maryland. *Manufacturers of Blast Cleaning and Dust Control Equipment—Rotoblast® Steel Shot and Grit.* ™

Let Rotoblast abrasives cut your cleaning costs.
A special heat treating process makes Rotoblast Steel Shot and Grit solid and tough, so that they can stand up to much more punishment than ordinary abrasives. Since they last longer, they can make many more passes than run-of-the-mill abrasives. Rotoblast Steel Shot & Grit can reduce your abrasive replacement costs considerably, and thereby decrease your cleaning costs.

Pangborn
OF HAGERSTOWN

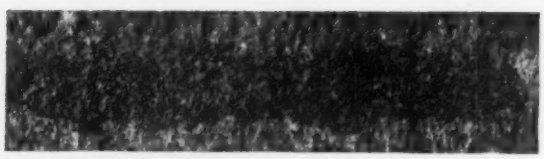
Circle 2094 on Page 48-E

Stainless cutting



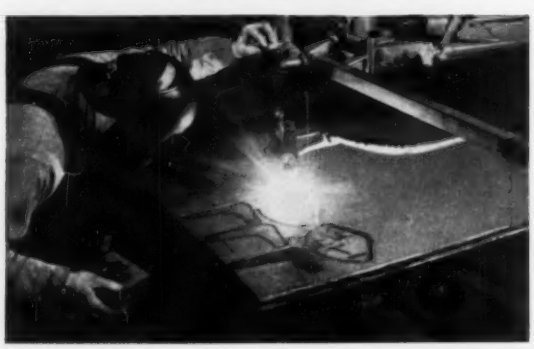
improved 5 ways

with Heliarc service from Ryerson Steel



Powder flame-cut stainless

Heliarc-cut stainless



This ultimate in stainless shape cutting is another Ryerson plus service. Ask about this service when the following advantages are important to you:

1. Clean edges free of powder contamination—and even smoother than hack-sawed edges.
2. Easier finishing because edge hardening is minimized.
3. Substantially less carbide precipitation (loss of corrosion resistance) than with any other flame cutting process.
4. Machining greatly reduced or eliminated—edges ready for welding or finishing.
5. Distortion and discoloration held to a minimum

METALOGICS
RYERSON PLUS VALUES

STEEL · ALUMINUM · PLASTICS · METALWORKING MACHINERY

RYERSON STEEL

Joseph T. Ryerson & Son, Inc., Member of the INLAND Steel Family

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Metal Progress

Vol. 78, No. 5 November 1960

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Fluid Bed Marks New Gain In Heat Treating

The introduction of a furnace which uses the principle of the fluidized bed signifies an important advance in heat treating. Unveiled last month at the Metal Show by General Electric's Industrial Heating Dept., Shelbyville, Ind., the new furnace takes advantage of the high heat transfer that can be obtained from refractory particles suspended as a turbulent cloud in a fluid.

The principle of the fluidized bed is simple: A fluid, either gaseous or liquid, is passed up through a layer of solid particles at such a rate that the particles are lifted and set into violent motion without being blown from their container.

What engineers at G.E. did was to contain the bed in an insulated jacket and supply a source of heat to the whirling cloud of particles. The result is a medium in which heat transfer between the primary heat source (electric heating elements or radiant tubes) or part and the bed of particles ranges from 70 to 130 Btu. per hr. per sq.ft. per °F., some 7 to 10 times higher than that obtained from convection alone. Another advantage is that high turbulence eliminates temperature gradients.

Fluid bed furnaces are not just laboratory toys but are emerging as real production tools. Boeing Airplane Co. in Seattle, for example, has recently placed a unit in a production line (see photo). The company's work with the medium has also emphasized its importance as a quenchant. Boeing engineers assert that the fluid bed system is equal to or superior to water and oil baths. Small metal parts quenched in a fluid bed from 1600° F. cooled to about 200° F. in 5 sec., a quenching speed obtained because of the absence of a vapor phase which forms on metal parts when they are

FLUID BED FURNACE AT BOEING
New Medium Provides High Heat Transfer

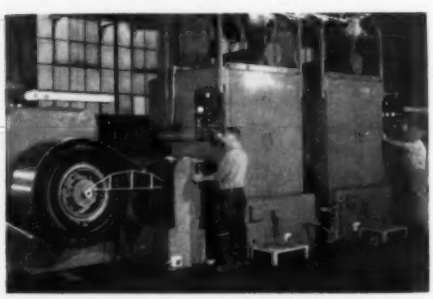
quenched in liquid baths. Boeing's experience has also shown that a wide temperature range from over 2000 to below −110° F. is feasible. (An article in a subsequent issue of *Metal Progress* will tell about Boeing's experience with the fluidized bed furnace for heat treating production parts.)

Belt Grinding Takes Role in Precision Finishing

Since 1935 when the first belt grinding machine made its appearance, coated abrasive belts have come a long way towards becoming a precision tool in the metals industry. Now, new machines (picture) capable of holding thickness variations across steel strip to no more than 0.0005 in. have been announced. This represents the culmination of eight years of work among engineers of Hill Acme Co., Cleveland; Behr-Manning Co., Troy, N.Y.; and Wallingford Steel Co., Wallingford, Conn.

Unique characteristic of the precision belt grinder is its ability to remove the crown from hot rolled strip. This is the ridge of extra thickness running along the longitudinal axis of the strip. It averages about 3% of the total thickness of the strip and is not removed by cold rolling. For most applications the few thousandths of an inch of extra metal involved is insignificant, but to weight-conscious engineers in aircraft and missiles it means excess weight which robs the payload. As an example, removing only 0.001 in. of metal from 100,000 sq.ft. of aircraft skin saves over 400 lb.

To meet the close tolerances demanded by the aircraft industry, Wallingford runs hot rolled strip (mostly stainless steel up to 0.240 in. thick) through a tandem setup of precision belt grinders before cold rolling it to desired thickness. Strip comes off a pay-off reel under 30,000 lb. tension, travels under a break roll which guides it at an angle (up to 20° from horizontal) between a vertical belt grinder and a steel billy roll which is hydraulically actuated to force the strip up against the belt. During grinding the belt is lubricated by a flood of sulphur-chlorinated mineral oil pumped in at 65 gal. per min. Contaminated lubricant drops to a 4000-gal. reservoir and filtration system.



PRECISION BELT GRINDERS
Thickness Variation in Steel Strip Held to ±0.0005 In.

Belts used in the machine are 30 in. wide by 126 in. For close tolerance work aluminum oxide or silicon carbide bonded with resin to X-weight backing cloth are used. These are driven by knurled steel rolls operating at 2100 surface ft. per min. The scratch pattern is removed by at least 60% reduction in thickness during subsequent cold rolling. Serrated rubber rolls ranging from 45 to 90 Durometer are installed in the machines where good surface finishes are the primary requisite.

Survey Predicts Bright Future for Stainless Steel

If the results of a recent market study hold true, it will mean that sales of stainless steel in the United States will exceed 1,000,000 tons per year by 1967, an increase of 87% over 1957.

The study, which surveys the market potential for stainless steel, is being carried out by International Nickel Co., Inc., New York. Of the 20 reports to be made on fields such as automotive, aircraft, chemical industry and metalworking equipment, two have already been released. These cover the outlook for stainless steels in appliances, utensils and cutlery and in food processing machinery. Total sales in these areas are expected to reach almost 120,000 tons annually by 1967, 76,000 tons of stainless steel in appliances, utensils and cutlery and 43,000 tons in food processing machinery.

Where will all the nickel come from? Some 75 million pounds annually are expected to be taken from Inco's new mine in Manitoba, Canada. Described as the second biggest nickel mine in the world, it will open in 1961.

Aluminum Applied to Steel by Vapor Deposition

Researchers at Wright Air Development Div. of the Air Force's Air Research and Development Command are coating steel with vapor-deposited aluminum. Significance of the process is that it opens the way for using complex steel shapes and fasteners in oxidizing environments at 500 to 1000° F. and reduces the danger of galvanic corrosion.

In the process, vaporized tri-isobutyl aluminum decomposes at 500° F. to cover steel parts suspended in the vapor with a layer of high-purity aluminum. Bond strength of the coating is good. In one test a sample was heated to 1000° F. for 1 hr. and quenched in cold water. There was no flaking.

More Interest in Direct Iron Processes

Judging from the recent conference of the American Iron and Steel Engineers held in Cleveland, steelmakers in this country are becoming more in-

terested in direct iron processing. For example, news of the new Dwight-Lloyd McWane process was coupled with the information that M. W. Kellogg Co. will erect a 300,000-ton-per-year plant in Mexico City based on the HyL process, and that a plant employing the H-Iron process is being built on the West Coast for Bethlehem Steel Co.

The Dwight-Lloyd McWane method, reported to be capable of 500 tons a day, ties together two familiar steelmaking appliances, the Dwight-Lloyd sintering machine and the electric furnace. It is a continuous process which starts with powdered ore, coal, and limestone. These three ingredients are thoroughly mixed and agglomerated – water is the binder – into small, moist pellets. After these pellets are dried and sintered in the D-L machine, they are dumped through the roof of a continuously operating electric furnace. As the iron forms, the furnace is tapped periodically. Iron can be pigged or used as hot metal for the open-hearth. The equipment can also be adjusted to produce white cast iron, gray cast iron, silvery pig iron or ferro-alloys.

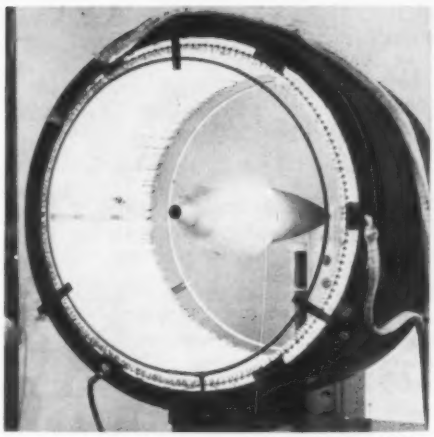
The HyL method for direct reduction requires large amounts of natural gas. (Full details of operation can be found in *Metal Progress*, January 1960.) Since Mexico has much cheap natural gas, the system has proven economical there. In fact, it was the achievements with the 200 and 500-ton-per-day plants at Monterrey that led to Hojalata y Lamina's decision to build the 300,000-ton-per-day mill at Mexico City. Iron supplied by the HyL method will be processed by electric furnaces, a continuous slab and billet casting plant and a rolling mill.

A large pilot plant for the H-iron process is being built by Bethlehem Steel Co. in Los Angeles. The installation, which reduces iron ore with dry hydrogen, is expected to produce iron briquettes at the rate of 100 tons per day. According to Hydrocarbon Research, Inc., New York, which designs and builds plants using the process, the main advantage is that coke is not needed. Instead, the hydrogen for reduction is obtained from gas or oil, both of which are easily obtainable in Southern California.

Quartz-Tube Furnaces Aid Missile Research

Quartz infrared tubes now used in office copying machines, heat lamps, and industrial baking and drying operations are proving useful in simulating thermal conditions which are encountered by missiles passing through the atmosphere. High temperatures can be reached in furnaces made up of an array of quartz tubes in a cylindrical radiator. Tests have been run at over 3100° F. (see picture, above); the potential limit is apparently governed by the melting point of the tungsten filament (about 6100° F.).

Lamps in use now can take about 200 watts per in. and have been operated at overvoltages up to



INFRARED TUBES HEAT NOSE CONE
Quartz Lamps Permit Tests at 3100° F.

1000 watts per in. for short periods. Work is being done on tubes which will operate at 360 watts per in., or 1500 watts per in. for a few seconds.

Uses for Depleted Uranium

The gaseous diffusion plants of the U. S. Atomic Energy Commission are continually making as a byproduct a considerable amount of "depleted" uranium – that is, natural metal which has been stripped of a major portion of the active U^{235} isotope. The remaining stable U^{238} exists in the form of a volatile fluoride and all of the fluorine can be separated and reused. It is low enough in radioactivity and toxicity so that remote handling is unnecessary.

Uses suggested for such metal are for radiation shields, X-ray targets, counter weights, reducing agents for molten metals, an alloying constituent in commercial steels, and for cathodic protection devices. Uranium oxide has an important use as a ceramic pigment, and has potential as a refractory. Present production exceeds consumption many fold.

Cold Working Improves Powder Metal Compacts

Very fine metal powders, especially those with oxidized surfaces, are difficult to press into coherent compacts and then to sinter into dense parts. Workers for the French Atomic Energy Commission find that this can be corrected if the powders are previously deformed by cold work, as by passing between two rolls driven at slightly different speed. This appears to shear or fragment the particles or to deform them enough so the oxidized layer is fragmented. The operation of compacting in dies,

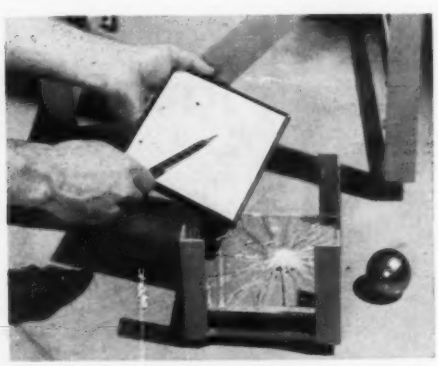
immediately following, will force into contact those areas where metal is bared, and "cold welding" will occur under the pressure. Using this technique, the apparent density of compacts made from lamellar aluminum powder has been increased from 0.45 to between 0.75 and 1.0.

Materials Progress in Graphite and Ceramics

Demands for materials capable of holding up at temperatures experienced in missile motors and high-performance aircraft are leading researchers to take a closer look at graphite. One of the most recent findings is a way to produce strong graphite by recrystallization. Announced by National Carbon Co., the process produces graphite which has a more uniform and compact structure than artificially produced varieties. Density of recrystallized graphite, like that of natural and pyrolytic graphite, approaches the theoretical value of 2.26 g. per cc. Cylinders 8 in. in diameter and 10 in. long have been made.

Properties of recrystallized graphite can be varied. Grain orientation, for example, can be controlled so that a set of properties suited for a particular high-temperature application is obtained. Flexural strength of the recrystallized material is about 6000 psi. at room temperature. As temperature goes up, strength increases, a characteristic of all artificially produced graphite. At 4500° F. it is about 12,000 psi. And, because of its low creep rate, recrystallized graphite is useful up to about 5500° F.

Another outcome of research in ceramics is a material which is expected to find structural applications in the process industries. Announced by the Pfaudler Co., the ceramic (called Nucerite) is chemically bonded to steel or heat resistant alloys such as Inconel and Hastelloy. Laboratory tests reveal that it can take more stress without deforming than mild steel, can protect molybdenum from oxidation at 1600° F. in an oxy-acetylene flame, its resistance to damage from thermal shock is 3 to 4 times that of existing glass-coated metals, its impact strength is better than safety plate glass by about 18 times (photo), and heat transfer is 6 to 10 times greater than ceramics now used in high-temperature service in corrosive environments.



NEW CERAMIC COATING RESISTS IMPACT
Bonded to Metal, It Makes Good Structural Material

From Here and There

Panels for interior and exterior architectural uses are being made by bonding Type 302 stainless steel sheet, 0.016 and 0.018 in. thick, to various core materials. Produced by Mirawal Div. of Birdsboro Corp. in Birdsboro, Pa., they range from 11/16 to 3 in. thick in 4 × 10 ft. sections. Biggest market is expected in exterior of buildings but the panels should also prove useful in the interiors of hospitals, schools and municipal buildings and in the food and chemical industries.

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Jones & Laughlin Steel Corp., Pittsburgh, announces three constructional steels which reach typical yield strengths of about 92,000, 107,000 and 114,400 psi. when quenched and tempered. They can be welded without preheat, preferably with low-hydrogen electrodes. Also introduced were two abrasion resistant grades which can be heat treated to a Brinell hardness of 340 to 380 and 400 (min.), respectively.

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Some $96,000 worth of Zircaloy tubes were shipped to Canadian General Electric Co. recently for Canada's first nuclear power station – a 20-megawatt prototype. Made by Chase Brass & Copper Co., each of the tubes are 14 ft. long and weigh 72 lb. They were extruded from copper-coated zirconium billets.

• • • •

Bellows expansion joints are now being made from titanium for a chemical processing application by Tube Turns Div. of Chemetron Corp., Louisville, Ky. The 18-in. joints will be used in a steam line. High chloride content of the steam had caused stress-corrosion cracking in stainless steel bellows which were formerly installed, thus limiting their life to about 30 days.

Silicon May Not Cause Decarburization

It may be a mistake to assume that silicon accelerates decarburization in medium-carbon alloy steels, a suspicion long held by heat treaters. In next month's *Metal Progress*, Peter Payson will offer data in his article "Does Silicon Accelerate Decarburization?" to show that what has been mistaken for decarburization is actually a separation of ferrite from austenite on cooling. Extra molybdenum or chromium increases hardenability to overcome this tendency.

Critical Points

By the EDITORS

Modern Ceramics: Ally of Modern Metals

Metals engineers, look out! The ceramist is breathing down your neck. Long regarded as nothing more than a maker of pottery and glass, the ceramics engineer is devising some extremely interesting rivals to metals. And guess how he has been doing this? By applying techniques the research metallurgist has used for years. For instance, single metallic crystals have inspired the ceramist to grow single crystals of his own. So we now have ductile ceramics – for example, single crystals of magnesium oxide.

This particular item of information is only a small part of a very interesting report (p. 88) of a recent conference on "engineering ceramics". Written by W. W. Austin of North Carolina State College, this report discusses the use of familiar metallurgical tests (tensile, microhardness, fatigue and the like) for studying ceramics, and the application of grain-boundary phenomena for devising new formulations. New ceramics are coming along in a constant flow, and some of them are superior to metals in ultra-high-temperature applications.

It is interesting to note that Dr. Austin's report ties in with another article along similar lines. In a recent issue of the *Research Laboratory Bulletin*, published by General Electric Co., J. E. Burke, manager of the ceramics studies section in G.E.'s Metallurgy and Ceramics Dept., discussed a number of advances in "the new science of ceramics". To quote: "These new materials have special properties needed for applications in nuclear energy, electronics, jet engines, rockets, and other new technologies. Some examples are uranium dioxide as a reactor fuel; aluminum oxide and graphite for high-temperature structural purposes; heavily doped magnetite as a magnetic core for high-frequency transformers; radiation-resistant glasses; and ceramic-metal composite cutting tools." He goes on to say that the new approach to the study of ceramics, since it requires knowledge of the chemical and structural variations responsible for changes in properties and behavior, has led to the name "physical ceramics", paralleling physical metallurgy. Researchers in this new field have come up with whiskers of aluminum oxide which withstand over 1,000,000 psi. stress. Glass fibers which resist a pull of several hundred thousand pounds per square inch have also been produced.

According to Dr. Burke, "The greatest need is for precise measurements of the behavior of carefully characterized materials since . . . small changes in composition or structure can produce striking changes in properties." This particular problem, of course, has been faced by metallurgists ever since they first realized that, when the composition of steel changed slightly, properties of the steel changed appreciably. (In other words, instead of wearing, a high-phosphorus rail would break.) It seems that metallurgical engineering will set the standards for the "materials engineering of the future" about which we hear so much these days for the needs of defense and industry. After all, it's the metallurgist who has been trained to think inherently of properties of material in relation to their composition, microstructure and atomic architecture. Now, with the ceramist as a companion, we may look forward to an ever increasing flow of materials designed to meet the needs of this demanding area. Separately, the metallurgist and the ceramist are each highly talented; in combination they can accomplish wonders.

How to Fabricate

Progress in High-Temperature Materials

One of the newest of the superalloys, this nickel-base alloy can retain high strength above 1400° F. Details on heat treating, welding and brazing are given. (J27, K-general; Ni-b, SGA-h)

ONE OF THE MOST IMPORTANT FACTORS in the advancement of supersonic aircraft design has been the development of alloys that retain high strength and oxidation resistance at elevated temperatures. The newest production alloy of this type is René 41*. A nickel-base austenitic alloy which is age hardenable, it gets its high-temperature strength from an intermetallic precipitate of a complex nickel-aluminum-titanium compound. René 41 has become a popular jet engine material because of its superior strength and oxidation resistance at

*Trademark of the General Electric Co. A typical analysis is 0.08% C, 0.50% Fe, 19.00% Cr, 11.00% Co, 9.75% Mo, 3.15% Ti, 1.50% Al, 0.006% B, remainder Ni.

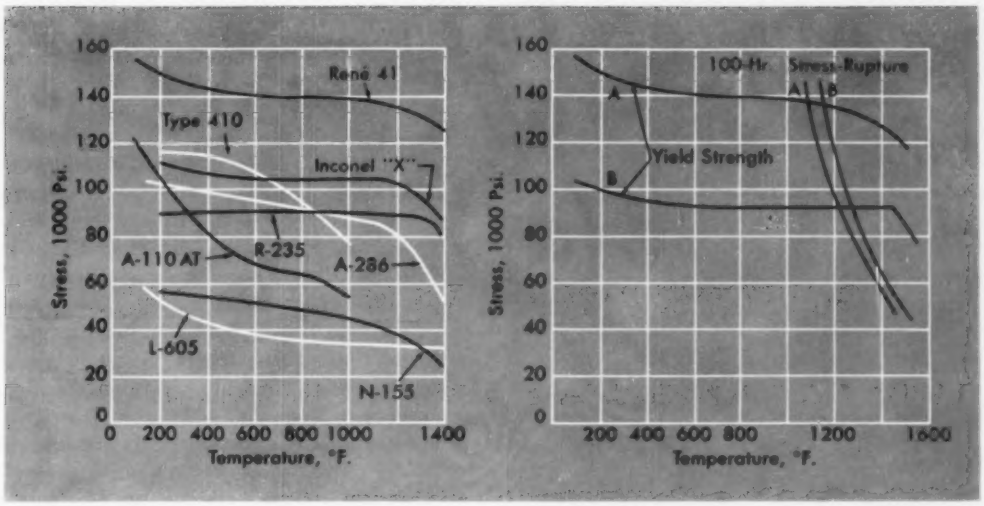


Fig. 1 – Yield Strength Comparisons of Various Sheet Alloys. The yield strength is determined at 0.2% offset

Fig. 2 – Effect of Heat Treatment on Yield Strength and Stress-Rupture Properties. For best tensile strength (A), solution treat at 1950° F., air cool to room temperature, and age at 1400° F. For best stress-rupture properties (B), solution treat at 2150° F., cool to room temperature, and age 4 hr. at 1650° F.

René 41

*By LOUIS A. WEISENBERG and ROBERT J. MORRIS**

Table I – Hardness Requirements for René 41

ANNEALED: 1975° F., OIL OR WATER QUENCH	
Sheet and strip (0.070 in. and under)	Rockwell C-27 max.
Sheet, strip and plate (0.071 in. and over)	Rockwell C-30 max.
Bar, forgings and flash welded rings	Brinell 321 max.
HEAT TREATED	
1950° F. solution, 1400° F. age	Rockwell C-35 min.
2150° F. solution, 1650° F. age	Rockwell C-30 min.

operating temperatures. The yield strength at 1400° F. is over 110,000 psi., and at 1200° F. is at least 25% above that of many other superalloys (Fig. 1). On a strength-to-weight basis, an important aircraft design criterion, René 41 is also excellent. The coefficient of thermal expansion is about one-third less than the 18-8 austenitic stainless steels, and is slightly higher than that of ferritic alloys such as Type 410 stainless steel.

Two heat treatments have been devised for René 41, the one to be used depending on whether the particular design calls for tensile strength or stress-rupture strength. For maximum tensile properties, solution treat at 1950° F. for 30 min., air cool to room temperature, and follow by a 1400° F. 16-hr. aging cycle. However, if optimum stress-rupture properties are desired, solution treat at 2150° F. for 30 min., air cool, and end with a 1650° F. 4-hr. age. Comparative properties for each treatment are presented in Fig. 2.

To keep the alloy soft for subsequent forming and welding operations, solution treat at 1975° F., and quench rapidly in oil or water. Table I lists the maximum Rockwell hardness values that our specification B 50-T 59 allows

*Mr. Weisenberg is metallurgical design specialist, jet engine department, Flight Propulsion Div., General Electric Co., Cincinnati, Ohio; Mr. Morris, formerly with G.E., is now with International Nickel Co., Inc., in Dayton, Ohio.

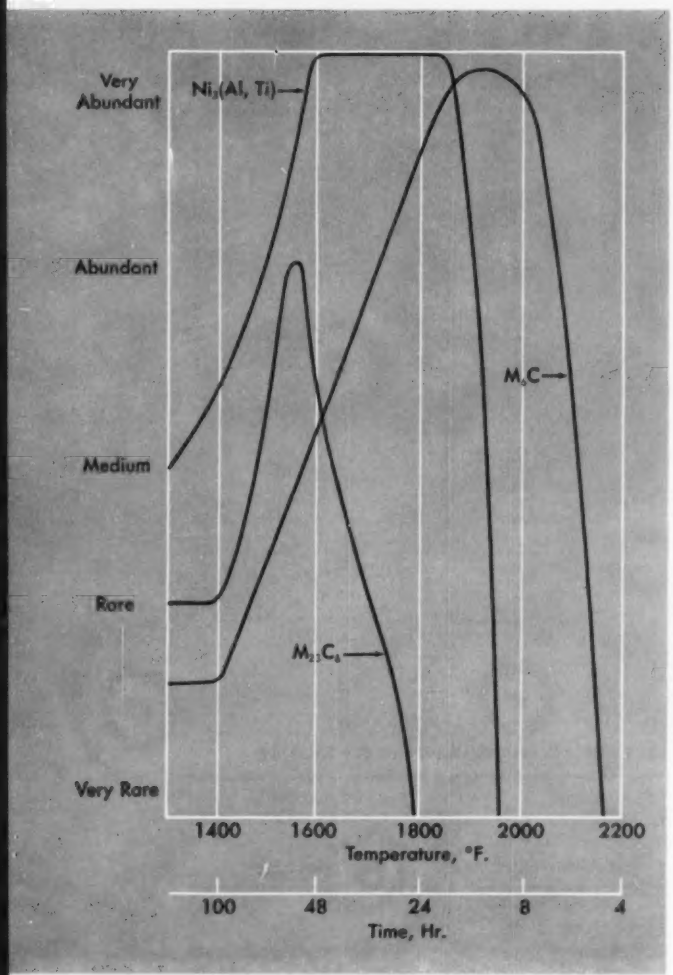


Fig. 3 – Isothermal Phase Reactions in René 41. Bar stock specimens were initially treated at 2200° F. and water quenched. After aging at the times and temperatures indicated, phases were extracted and examined by X-ray diffraction

for mill annealed René 41; hardness minimums for each heat treatment are also given.

Microstructure

René 41 is quite typical of the precipitation hardening, nickel-base class of alloys in some respects. All of them derive their high-temperature strengths primarily from intermetallic compounds dispersed in a f.c.c. matrix of nickel-rich solid solution. In this alloy, the $Ni_3(Al, Ti)$, or gamma prime (γ') phase, forms as the alloy is aged. The amount, particle size, and distribution account for the high strength levels from room temperature to well over 1400° F. This γ' can form as low as 1100° F. (especially in cold worked regions), but is most prevalent from 1400 to 1850° F. (Fig. 3). Particle size increases with temperature of formation, and the γ' dissolves completely at about 1925° F.

The rate of γ' precipitation is extremely rapid at 1400° F. (15 points Rockwell C increase within 2 min.). For this reason, the alloy *must* be quenched from the annealing temperature within seconds to prevent γ' from precipitating. The 1975° F. annealing temperature is slightly higher than the 1950° F. solution temperature; this aids mill quenching of large sheets and insures successful softening. When René 41 is air cooled from either 1950° F. (the solution temperature for best tensile strength) or 2150° F. (the solution temperature for best stress-rupture properties), the hardness will probably be greater than Rockwell C-30.

Other significant phase reactions involve the two carbides, $M_{23}C_6$ and M_6C, the latter of which is the stable carbide at higher temperatures. The working operations involved in producing the various mill forms of René 41 result in a uniform, fine-grained material with relatively small, discrete particles of M_6C dispersed throughout the structure. The 1975° F. mill anneal, the 1950° F. solution, and 1400° F. age merely dissolve and precipitate the γ' phase; the M_6C carbide is not disturbed since it is not dissolved at these temperatures.

If the alloy is heated to about 2150° F., the M_6C dissolves and grain growth occurs. When the alloy is then reheated (as it would be in any subsequent heat treatment operation), the carbon will precipitate quickly at lower temperatures (1400 to 1550° F.) as $M_{23}C_6$. This is totally undesirable because this new carbide will form continuous grain-boundary films around the new large grains. A metal of lower ductility results. Hence, the heat treatment which has hardened and strengthened the alloy (by precipitating γ' within the grains) has simultaneously produced a brittle grain-boundary network. (We learned about this condition when some highly restrained parts were welded of alloy annealed at 2150° F.; they cracked badly with subsequent heat treatment.)

To summarize briefly, the 1975° F. water quench treatment anneals or softens René 41 by dissolving the γ'. The M_6C is not dissolved and a fine grain is retained. The 1950° F. + 1400° F. treatment promotes maximum tensile strength; rupture properties will be lower due

to small grain size (A.S.T.M. 5 to 7). The 2150° F. + 1650° F. cycle develops optimum stress-rupture properties because of M_6C solution (with subsequent precipitation as $M_{23}C_6$) and grain growth (A.S.T.M. 1 to 3). This results in somewhat lower tensile properties. Hence, the heat treatment is tailored to suit the particular application involved.

Welding Is Tricky

In welding René 41, assemblies which are consistently sound can *only* be made by using the proper welding procedures. Recommendations are as follows:

- Material must be properly annealed before welding.
- Good fit-up is absolutely necessary.
- Copper and argon backing should be used whenever possible.
- Gas coverage on both sides is mandatory on all butt joints.
- Joint edges should be ground to remove burrs before welding.
- Control of arc length and current is helpful for minimum heat input.
- Automatic welding is preferred to manual welding.

Because the alloy has only a small tolerance for variations, any careless welding will probably result in cracks during welding or subsequent heat treatment. However, once the proper precautions are established, the alloy can be welded on a production basis in a routine manner.

The molten weld metal must be protected from atmospheric contamination; this cannot be too strongly emphasized. Fillet welds on sheet stock less than 0.030 in. should be both metal and gas backed; otherwise cracks or "burn-through" will occur. Butt joints that are not gas covered on both sides will show an oxide line at the root of the weld bead.

Though René 41 filler wire is available, it is not essential for high-strength joints. The best filler material for "low"-temperature applications (to 1400° F.) has been Hastelloy W; above 1400° F., Hastelloy X is better. The latter alloy is necessary at the higher temperatures because its higher chromium (22% instead of 5%) gives better oxidation resistance. A comprehensive evaluation of various fillers showed that butt joints welded with Hastelloy W and Hastelloy X had 80 to 85% of the strength of the parent metal, along with good ductility as measured by tensile tests from room temperature to 1600° F. This apparent anomaly of weaker materials (Hastelloy W and X) showing high joint strengths is easily explained; during welding they melt, flow readily, and are strengthened by dilution with the René 41. Many other filler materials do not possess these desirable characteristics.

Successful experience in fabrication of René 41 may be summarized as follows:

1. René 41 must be in the 1975° F. mill annealed condition prior to forming or welding.
2. Welding on cold worked parts should be avoided. Any necessary in-process anneals should be a 1975° F. treatment followed by a rapid quench.
3. Strain age cracking can be avoided by charging welded components into a hot furnace (1970° F. minimum) to reach the solution temperature as rapidly as possible. This minimizes the time in the aging range.
4. Weld designs and procedures that minimize weld restraint and heat input are most important for the consistent fabrication of good parts.
5. The preferred inert arc filler materials for high-strength weldments are Hastelloy W and Hastelloy X.

Welding aged René 41 is virtually impossible. The surest and cheapest way to build a part which will have the strength capabilities inherent in the alloy is to *do it right the first time*. If any major cracks appear after aging, the part will have to be annealed prior to repair welding.

The proper weld design can make it much easier to manufacture parts of René 41. Where it is possible, the design should avoid welds that result in high residual stresses due to weld shrinkage or "built-in" notches that could be sites for fatigue failures to start. Figure 4 shows acceptable weld designs for René 41. These features may result in slightly more weight or increased machining, or both. However, quality cannot be consistently maintained without incorporating them into the design.

Brazing Also a Problem

The brazing of René 41 also offers difficulties because most high-temperature brazing alloys are nickel-base materials which contain boron or silicon, or both. They severely attack the

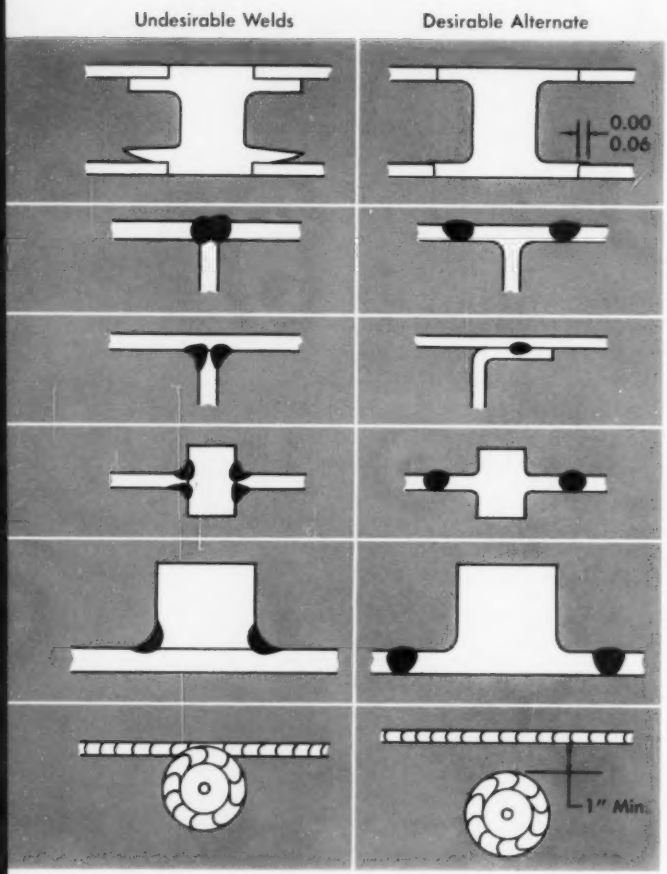


Fig. 4 — Acceptable Weld Designs for René 41

alloy intergranularly. Silver brazes do not attack René 41, but they are limited to low temperatures (600° F.). This would seriously limit the applications of the alloy. René 41 must be brazed in a dry hydrogen atmosphere or in a vacuum to prevent the aluminum and titanium (present in the alloy) from oxidizing. Such oxides, of course, would prevent a high strength bond.

If parts are nickel plated before brazing, erosive and embrittling effects of boron-containing alloys on René 41 are lessened. Failure, however, occurs in shear through the plating; this results in low strengths. Efforts are now being made to develop boron-free brazing alloys that would not erode or embrittle René 41.*

Fabricating Difficult, at First

Initially, fabrication of René 41 (mill annealed with a 2150° F. water quench treatment) was marred by numerous failures. Since this annealing cycle put the alloy in the "dead soft" condition, it could be formed by conventional methods without difficulty. Welding also appeared simple, verifying laboratory data which indicated that René 41 was easier to weld than A-286. However, these parts could not be subsequently solution treated without serious cracking in the heat-affected zone. If parts were aged directly after welding, the cracking was even more severe.

This cracking was due to "strain aging", a phenomenon caused by stress from microstructural changes due to the γ' precipitation and the formation of $M_{23}C_6$ at the grain boundaries. Since these stresses were superimposed upon areas which were already at high residual stress levels from the welding sequence (due to thermal expansion and weld shrinkage during solidification), the result was immediate and emphatic fracturing in the heat-affected regions. In René 41 this cracking occurs when welded areas are held within or slowly heated through the aging range, 1100 to 1850° F.

This dilemma has been overcome by lowering the mill anneal temperature to 1975° F. and by charging welded components into a "hot" furnace to be heated through the aging range as quickly as possible. For example, if the part is to be treated at 1950° F., the furnace may be set at 2100° F. and cut back to 1950° F. after the part is charged.

Admittedly, the 1975° F. treatment does not produce the maximum in formability that the 2150° F. temperature gives, but formability is still considered "good". It amounts to 80 to 90% of that given the higher-temperature anneal. This slight compromise *must* be made to insure the success of subsequent welding and heat treatment.

René 41 is a high-strength alloy and work hardens rapidly. Consequently, it is difficult to machine. Nevertheless, production machining is practical with proper techniques. Carbide tools of the throwaway insert type are recommended, where applicable, to eliminate grinding. Rough machining is usually conducted on solutioned stock for maximum tool life; finish machining is done on aged material. Sulphurated oils have been found to give the best cutting results. For comparative purposes, René 41 can be considered to have one-third the machinability of A-286.

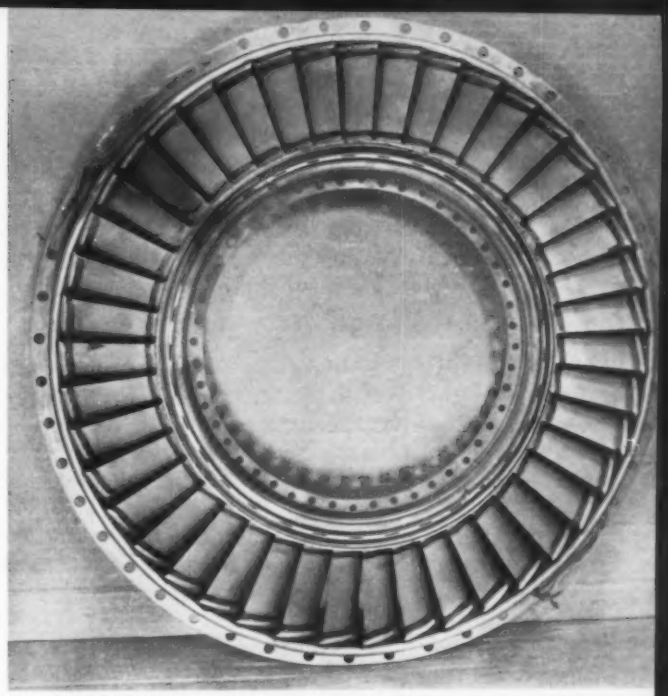
*A more comprehensive discussion of brazing can be found in the article immediately following, on the opposite page.

Progress in High-Temperature Materials

Brazing René 41

*By G. S. HOPPIN III**

Three brazing alloys have been devised; each answers specific needs. The type producing the strongest joints (J-8600) is used to braze the uncoated alloy in a vacuum; the others will braze nickel-plated René 41 in hydrogen. (K8; Ni-b, SGA-h)



J 79 Engine Nozzle Assembly, About 3½ Ft. in Diameter, Made by Brazing René 41

IN BRAZING ANY PART for high-temperature service, several important factors must be considered. These can be grouped into those factors that take effect during processing of the part, and those that are active during the service life of the part. For clarity, each set of factors will be discussed separately. Processing factors include the brazing atmosphere, solidus and liquidus temperatures of the brazing alloy, melting point and heat treatment of the base metal, intended service temperature of the part, reactions between the brazing alloy and the base metal, and the size of the gaps to be filled by the brazing alloy.

The composition of the base metal will dictate the type of brazing atmosphere permissible. This is also true of some brazing alloy compositions. For example, many superalloys can be brazed in a purified ("dry") hydrogen atmosphere. However, dry hydrogen cannot be used for alloys high in reactive elements such as aluminum (1.5%) and titanium (3.0%). Both elements are so reactive that their oxides actually form when the alloy is heated even though the dry hydrogen contains only a few parts per million of oxygen. Instead, this type of alloy must be brazed in a high vacuum (30 microns or less) unless the surfaces are protected by special treatment, such as nickel plating.

Composition of the brazing alloy can also determine permissible brazing atmospheres. For instance, brazing alloys containing reactive elements must be applied under vacuum for the same reasons as base metals high in such elements. However, a word of caution here. Brazing alloys containing large amounts of elements with high vapor pressures (zinc, for instance) cannot be employed successfully in vacuum because such elements evaporate.

The solidus and liquidus temperatures of the brazing alloy must be below the melting point of the base metal and must also be above the ultimate service temperature of the part being brazed. Ideally, the solidus and liquidus temperatures of the brazing alloy should be such that the brazing temperature is the same as the recommended solution treatment temperature of the base metal. This ideal is difficult to attain.

Interface reactions between the brazing alloy and parent metal should be such that the base metal is not eroded or embrittled. Otherwise, even if the part can be put in service, it will certainly not last for any appreciable time.

Gaps between separate sections of the parts

*Manager, Metallurgical Processes Unit, Flight Propulsion Div., General Electric Co., Cincinnati, Ohio. This article includes information presented at Golden Gate Metals Conference, San Francisco, Feb. 5, 1960. The author is indebted to Paul Miskulin, Kenneth Kulju, Ernst Huschke, William Blackham and Paul Mobley for the brazing studies and brazing alloy development work, to Vincent Poynter and Clarence Lehmann for the fine metallographic work, and to Joseph Japka and Richard Benson for the vacuum melting work.

to be ultimately brazed influence the choice of brazing material. If the gaps are to be of capillary size (0.001 to 0.005 in.), the brazing alloy should flow freely. However, when the gaps are wider, a sluggish brazing material is needed.

Service Factors Also Important

While the foregoing factors are important during processing, another group of service factors influences the selection of the brazing material for any given part. These are service temperature, strength of brazed joints at service temperature, oxidation resistance of the brazing alloy at the maximum service temperature, reactions between brazing alloy and base metal in service, and effect of the brazing thermal cycle on parent metal properties.

Since the maximum service temperatures for such brazed parts may be as high as 2000° F., strength and oxidation resistance of the brazing alloys are highly demanding factors. These largely determine whether or not the part will stand up in service.

Fig. 1 — René 41 Embrittled by Commercial Brazing Alloy. The intergranular penetration is thought to be caused by the presence of boron and silicon. Etchant, Marbles Reagent; 250 ×

While the problem of reactions between base metal and brazing alloy in service is not as severe as the occurrence of the same reactions during brazing (since service temperatures are lower than brazing temperatures), it cannot be overlooked. Service life of brazed parts at elevated temperatures will be several hundred hours, whereas the time at the brazing temperature will generally be 30 min. or less.

As mentioned before, brazing temperature should be closely matched to the solution temperature of the base metal. However, in most real situations, the two temperatures (brazing and parent metal solution) do not exactly match. Of equal importance, the cooling rates from the brazing temperature are seldom as rapid as the ideal ones for complete solution treatment. As an example, René 41 must be water quenched from 1950° F. for complete solution treatment. One can hardly water quench an assembly held together by a molten brazing alloy! Consequently, the actual thermal cycle experienced by a high-temperature alloy part during brazing always differs from recommended solution treatment practice. This may be partially remedied by solution treating and aging the brazed part at temperatures below the brazing alloy solidus, or the part may merely be aged following brazing.

In any event, the thermal history of the finished part rarely coincides with the recommended heat treatment on which design curves for the base metal have been developed. Consequently, the effect of this "combination" heat treatment must be ascertained to determine whether or not the part will have enough strength and ductility for its intended service.

René 41 Is Typical

To sum up, the problems met in brazing any given superalloy are many and varied. We will now see how they were solved for one typical alloy of this type, René 41. This alloy is a nickel-base, high-temperature alloy which derives its strength from the age hardening effects of titanium and aluminum. Because of its high yield strength and excellent stress-rupture properties*, it is currently being considered for use in some of the newer aircraft and missiles. Its combination of properties has made René 41 a logical candidate for brazed fabrications to be used between 1000 and 1800° F. Consequently, the alloy has been thoroughly investigated.

*See "How to Fabricate René 41", by L. A. Weisenberg and R. J. Morris, p. 70, this issue.

During this work, all of the critical factors previously mentioned have been closely examined.

When work began in 1957, the contemplated application was one in which large clearances for brazing were anticipated. Consequently, we first tested a brazing metal which had previously been developed for "wide-gap" applications. This alloy was a mechanical mixture of powders representing two nickel-base alloys. Specifically, the mixture contained 60% nickel with 1.9% Si and 0.7% B plus 40% nickel with 7.5% Cr, 4.5% Si and 3.3% B. We can compare the action of this mixture to that of concrete; a liquid slurry of cement (the Ni-Cr-Si-B alloy) freezes around the solid aggregate particles (the Ni-Si-B alloy).

Previously, this particular mixture had successfully brazed gaps up to 0.060 in. in parts made of A-286. Furthermore, alloys containing titanium and aluminum could be brazed in hydrogen when this alloy was used. The boron present in the brazing alloy mixture acted as a flux to remove surface oxides of titanium and aluminum formed in dry hydrogen brazing.

Early experiments showed that sound brazes of René 41 could be made in hydrogen at 2150° F. with the wide-gap brazing material. However, when a series of lap and butt joints were brazed and machined for mechanical tests, difficulties began to arise. Fourteen successive butt-joint specimens fractured in the braze when end milled. Microscopic examination showed that brittle fractures had occurred through a hard eutectic phase that was present as a continuous network throughout the brazed joints. When the specimens were shaped by grinding (instead of machining), stresses were minimized; this eased the brittle cracking.

But a far more serious problem then appeared. On testing the lap joints, brittle fractures occurred in the parent metal. A photomicrograph of one of these joints at the point of failure (Fig. 1) shows it to be completely intergranular in nature. The dark etching zone at the interface is composed of small particles of an intermetallic phase formed when alloying constituents from the brazing material penetrated the René 41.

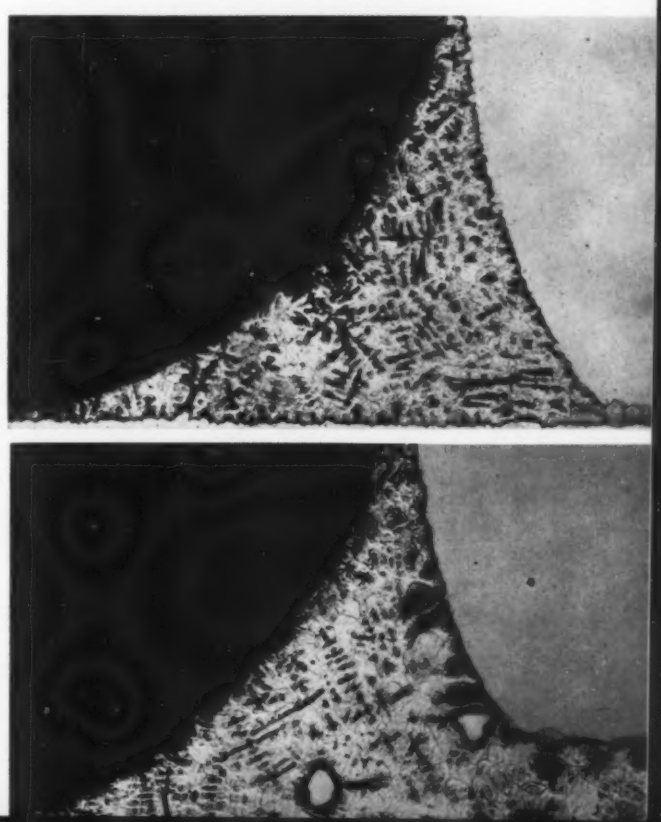
This penetration occurred in two modes. First, a dark etching layer (consisting of a great number of fine particles) formed. The second mode, probably the more damaging, was the formation of a brittle grain-boundary network which extended several thousandths of an inch below the surface of the braze interface. Subsequent experiments indicated that the damage was mainly done in brazing; little harmful diffusion occurred in the heat treatment steps.

More Work Needed

At any rate, regardless of the mechanism of attack, the wide-gap brazing material embrittled the alloy. We had to find a better brazing metal for René 41, and began to study two other commercial nickel-base brazing alloys. These were J-8100 (19% Cr, 10% Si) and A.M.S. 4775 (13% Cr, 3.5% Si, 3.5% B). Two series of lap joint test specimens were brazed, one set in vacuum, the other in hydrogen (after nickel plating the René 41).

In these tests, neither brazing alloy was successful, but nickel plating effectively inhibited embrittlement by the brazing alloys used. Apparently the nickel plate absorbed sufficient boron and silicon so that they did not penetrate the René 41. Though nickel-plated joints were weak (because they sheared in the weak layer of plate), shear strengths were still high enough to be useful. At room temperature, the strength

Fig. 2 – René 41 Brazed With Experimental Alloy J-8500 and Oxidation-Tested at 1200° F. (Top) and 1400° F. (Bottom) for 100 Hr. This brazing alloy is fairly sluggish; it is useful for brazing parts with wide gaps. The alloy must be nickel plated and brazed in hydrogen. Etchant, Marbles Reagent; 75 ×



was 35,000 psi., falling to 8000 psi. at 1800° F. for J-8100, the strongest of the two alloys.

So the brazing problem was partially solved. The solution was still incomplete, since J-8100 was a capillary brazing alloy, and a wide-gap brazing material was needed for René 41 in certain applications. Also, a vacuum brazing material that could be used with unplated René 41 was still desired.

Special Brazes Are Devised

Since the standard types of high-temperature brazing alloys had embrittled René 41, it seemed necessary to try wide-gap brazing with less common alloys. These evaluations led to new compositions specifically tailored for brazing René 41. Five other compositions were selected for brazing experiments. One was a commercially available silver-palladium-manganese alloy (termed SPM-1); the other four were experimental compositions devised in our laboratory. One of these had a cobalt base, the other three contained indium. All were brazed between 2150 and 2175° F.

The alloys were applied as powder slurries to the surface of René 41 panels. These panels were then brazed in hydrogen for 10 min. in the 2150 to 2175° F. range. After brazing, they were examined microscopically. The SPM-1 alloy caused some intergranular attack, while the cobalt-base alloy drastically eroded the René 41. In contrast, the three indium-containing alloys did not damage the alloy.

Oxidation tests of these brazes (at 1200 and 1400° F.) showed that 50% Cu, 35% Ni, 15% In alloy was the best of the three. However, its 1400° F. oxidation resistance was inadequate, and the 1700° F. solidus temperature was too low for an alloy brazing at 2150° F. (Wide melting ranges promote liquation – the separation of brazing alloys during heating.) Therefore, a series of Cu-Ni-In alloys was prepared, and evaluated for oxidation resistance, solidus and liquidus temperatures, and compatability with René 41. The best of these alloys was J-8500 (60% Cu, 35% Ni, 5% In), which had good oxidation resistance at 1400° F., a 1900° F. solidus and a 2200° F. liquidus, along with good compatability to the superalloy when brazed at 2200° F. The alloy was also sluggish; thus it filled our need for a wide-gap braze. Figure 2 shows the microstructure of J-8500 brazed joints in René 41 after oxidizing 100 hr. at 1200° F. and 1400° F.

Though laboratory tests showed that J-8500 would braze to the alloy reasonably well in hydrogen (presumably due to some fluxing action by the indium), nickel plating was required for actual parts brazed in a larger furnace. With this technique, large parts made of nickel-plated René 41 have been brazed in production with the J-8500 alloy. Lap joints of nickel-plated René 41, gapped 0.010 in. and brazed with this alloy, have shown shear strengths ranging from 44,000 psi. at room temperature to 18,000 psi. at 1250° F.

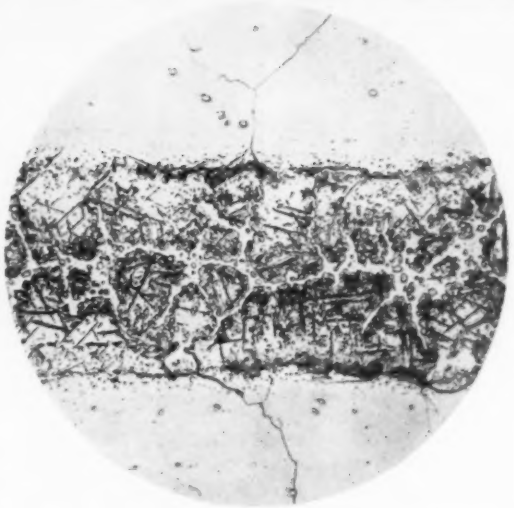


Fig. 3 – Joint Brazed With J-8600 in Vacuum. This alloy, which contains chromium, palladium, and silicon in a nickel base, was the best found for brazing René 41. Etchant, aqua regia; 250 ×

Since the nickel plating remained an undesirable additional operation (particularly on large fabrications), the next step was to find an alloy suitable for vacuum brazing. J-8100 could not be used, because it embrittled René 41 when no nickel plating was present. J-8500 could not be used because the indium vaporized in vacuum; thus the alloy would not braze.

Palladium Alloy Used

Some experience with brazing alloys of the Ni-Cr-Pd system had been gained in brazing studies on molybdenum. Though brazing temperatures of these alloys were excessively high for René 41, we felt that an alloy with a suitable brazing temperature could be evolved. Some 44 experimental compositions later, one was! The magic composition turned out to be a nickel-base alloy, containing 33% Cr, 24% Pd, and 4.0% Si. This alloy, which we called J-8600, brazed René 41 excellently in vacuum at 2150° F. with virtually no erosion or interface embrittlement of the base material (Fig. 3). It also has exhibited good oxidation resistance to

Tips for Brazing René 41

1. This alloy should be brazed in vacuum, or nickel plated if brazed in hydrogen.
2. Commercial brazing alloys high in boron or silicon (or both) embrittle René 41 badly.
3. The best method of brazing this metal is with a Ni-Cr-Pd-Si alloy (J-8600) in vacuum.
4. Alternate alloys for hydrogen brazing René 41 (nickel plated) are a Ni-Cr-Si alloy (J-8100) and a Cu-Ni-In alloy (J-8500).
5. The thermal cycles involved in brazing with these alloys lower the tensile properties of René 41 about 10%.

1500° F., and lap joints brazed in René 41 with this alloy have had shear strengths of 35,000 psi. at 1250° F. The alloy also possesses intermediate fluidity – it has brazed capillary and moderately wide-gap joints (up to 0.030 in.) with equal facility. Of even greater significance, a total of seven complex René 41 fabrications have been successfully brazed in a large commercial vacuum brazing furnace.

Summing up the brazing alloy studies on René 41: *(a)* Standard brazing alloys have been ruled out unless nickel plating is used; *(b)* J-8100 is the best of the standard alloys to use with nickel plating; *(c)* a Cu-Ni-In alloy (J-8500) is a satisfactory wide-gap brazing alloy to use on nickel-plated René 41 in hydrogen; *(d)* a new Ni-Cr-Pd-Si alloy (J-8600) has proved to be an excellent vacuum brazing alloy for René 41. (All compositions are listed in Table I.) These are simple conclusions, yet more than two years of work was needed to reach them.

Though many of the brazed parts being manufactured from René 41 should receive the 1950° F. solution treatment followed by a 1400° F. aging treatment, they do not because brazing temperatures are in the 2150 to 2200° F. range. For this reason, the effect of these brazing temperatures on mechanical properties of René 41 has been investigated. The most recent investigation has involved tensile property determinations on René 41. Specimens were run through two 2150° F. brazing thermal cycles in a production furnace, and subsequently solution treated at 1950° F. for 1 hr., air cooled, and aged 16 hr. at 1400° F. In Table II, tensile tests on these samples are compared with similar tests on control samples given the ideal heat treatment only. (All results are the average of three tests.)

When these test specimens were examined microscopically, we found that those which had received the brazing cycle had larger grains than those with the normal heat treatment. The average drop in tensile and yield strengths which results from brazing is little greater than 10% – not desirable, but certainly within design limitations on most parts.

As regards high-temperature materials in general, this work has shown that the alloy and process for brazing must be selected with a sound understanding of both the physical metallurgy of the base material and the interactions of the base material with brazing alloys. The effect of brazing thermal cycles on properties of the parent material must also be assessed to see whether compromises will be required in design assumptions. If these factors are property considered, sound, reliable brazed parts will result – if they are ignored, some very expensive scrap will be available!

Table I – Brazing Materials for René 41

	J-8600	J-8100	J-8500
Composition	39 Ni, 33 Cr, 24 Pd, 4 Si	71 Ni, 19 Cr, 10 Si	60 Cu, 35 Ni, 5 In
Brazing temperature	2150° F.	2200° F.	2200° F.
Brazing atmosphere	Vacuum	Hydrogen*	Hydrogen*
Service temperature	1500° F.	1900° F.	1400° F.

*Base metal must be nickel plated.

Table II – Effect of Brazing Cycles on Mechanical Properties

Specimens*	Test Temperature	Tensile Strength	0.2% Yield Strength	Elongation
Controls	Room	167,000 psi.	139,000 psi.	5.5%
Braze cycle + H.T.	Room	156,000	121,000	7.5
Controls	1200° F.	162,000	124,000	7.0
Braze cycle + H.T.	1200	143,000	111,000	5.5

*Control samples given ideal heat treatment only; brazed specimens run through two 2150° F. brazing thermal cycles.

Progress in High-Temperature Materials

Refractory Metals for Air and Space Vehicles

*Reported by R. H. GASSNER**

At a recent West Coast conference, engineers discussed applications, fabrication methods and properties of refractory metals as related to their use in aircraft and space vehicles. Most of the research so far has centered around molybdenum, columbium, tantalum and tungsten. Main drawback: at high temperatures, all of them have very low resistance to oxidation.
(T24, Q-general; EG-d, SGA-h, 17-57)

THE REFRACTORY METALS — in particular, molybdenum, columbium, tantalum and tungsten — are now receiving much attention because of their potential for missile and rocket applications. As a consequence, metals engineers in Southern California, a major center of the aerospace industry, were attracted in large numbers to a regional conference on the subject, and found, as this report shows, that progress has been made, though many problems still obstruct full utilization of refractory metals in the race to the stars.

The heat generated by hypersonic aircraft and re-entry vehicles poses a challenging problem for the structural designer because he has a difficult choice to make. He must either shield his structure from this heat by combining insulation and cooling techniques or make it from metals which will retain useful strength at temperatures above 2000° F. The first alternative has the advantage of using materials whose technology is relatively well developed, but the second offers extremely attractive weight savings. This was brought out in the paper presented by E. G. Czarnecki (Boeing Airplane Co.) who discussed three solutions for the primary structure problem: ablation cooling, insulation plus water cooling, and radiation cooling.

As described by him, the first concept requires only superalloys; the second employs superalloys for structure with a heat shield of refractory metal; and the third uses only refractory metals. The later two concepts are 640 lb. and 860 lb. lighter, respectively, than the first — and weight savings of this magnitude would be very attractive in today's supersonic aircraft — not to speak of tomorrow's Mercury capsule and Polaris missile illustrated here. Consider how much more appealing they must be to the designer of a vehicle to land on the moon and return to earth. Even assuming that tomorrow's high-energy propellants will be practical, the designer is faced with launch-to-payload ratios of 146 to 1.

Re-entry from outer space will impose the most severe heat rates on structures. They will be manifested by a high short-time heat pulse on the first bounce, and a low long-time pulse following. Fortunately, the maximum loading and maximum temperature are out of phase (in

*Chief Metallurgist, Douglas Aircraft Co., El Segundo Div., El Segundo, Calif.; Consulting Editor, *Metal Progress*. This report covers the 1960 Southern California Regional Conference sponsored by the Los Angeles, San Diego and San Fernando Chapters of the A.S.M.

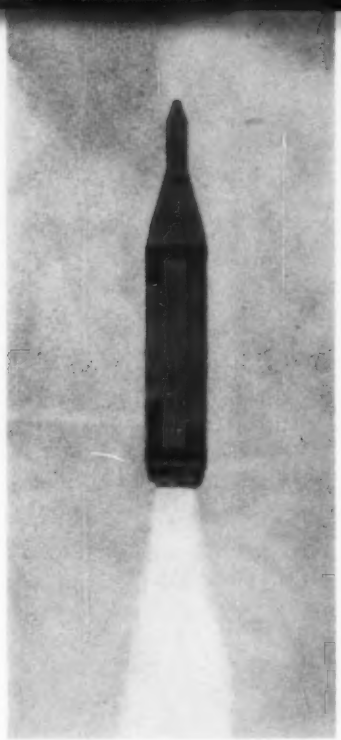


Fig. 1 – Polaris Test at Cape Canaveral

other words, the primary structure is quite lightly loaded at maximum temperature). Hence, most panels can be built of minimum-gage sheet. As an example, 0.008-in. face sheet backed by 0.010-in. corrugations, 18 in. apart, may be used. Flexible connections will compensate for major thermal loads.

Refractory metals may also be used in ramjet-powered vehicles, low-altitude missiles, and heat dissipation systems in satellites. The first two, operating in the atmosphere at Mach 2 to 6 for hours rather than minutes, will require oxidation resistant coatings. Satellites, however, may need the corrosion resistance of refractory metal tubing for the liquid sodium used to carry away the heat generated by solar radiation and internal electronic equipment.

Strength-to-density evaluations show columbium and molybdenum to be far superior to tungsten and tantalum for such applications – if the temperature stays below 2500° F. Above this temperature, molybdenum and tantalum are about equal, but tungsten is better still, as Fig. 2 shows. However, its high ductile-to-brittle transition temperature, 645° F., presages difficult handling and workability problems. The transition temperature of molybdenum, about 75° F., indicates that some minor inconviences may be required in its fabrication. Columbium and tantalum, with transition temperatures well below zero (−185 and −320° F., respectively), can be formed satisfactorily. Figure 3 illustrates the transition temperature characteristics.

In structural applications of refractory metals, lack of oxidation resistance at high temperatures is a critical problem. Despite minor differences in oxidation rate, all of them will require protective coatings when used in re-entry vehicles. The useful limit for coatings now developed is about 3000° F. Reliable coatings which can withstand 4000° F., and whose effects on design properties are known, will be needed if the full potential of refractory metals is to be realized in vehicular structures.

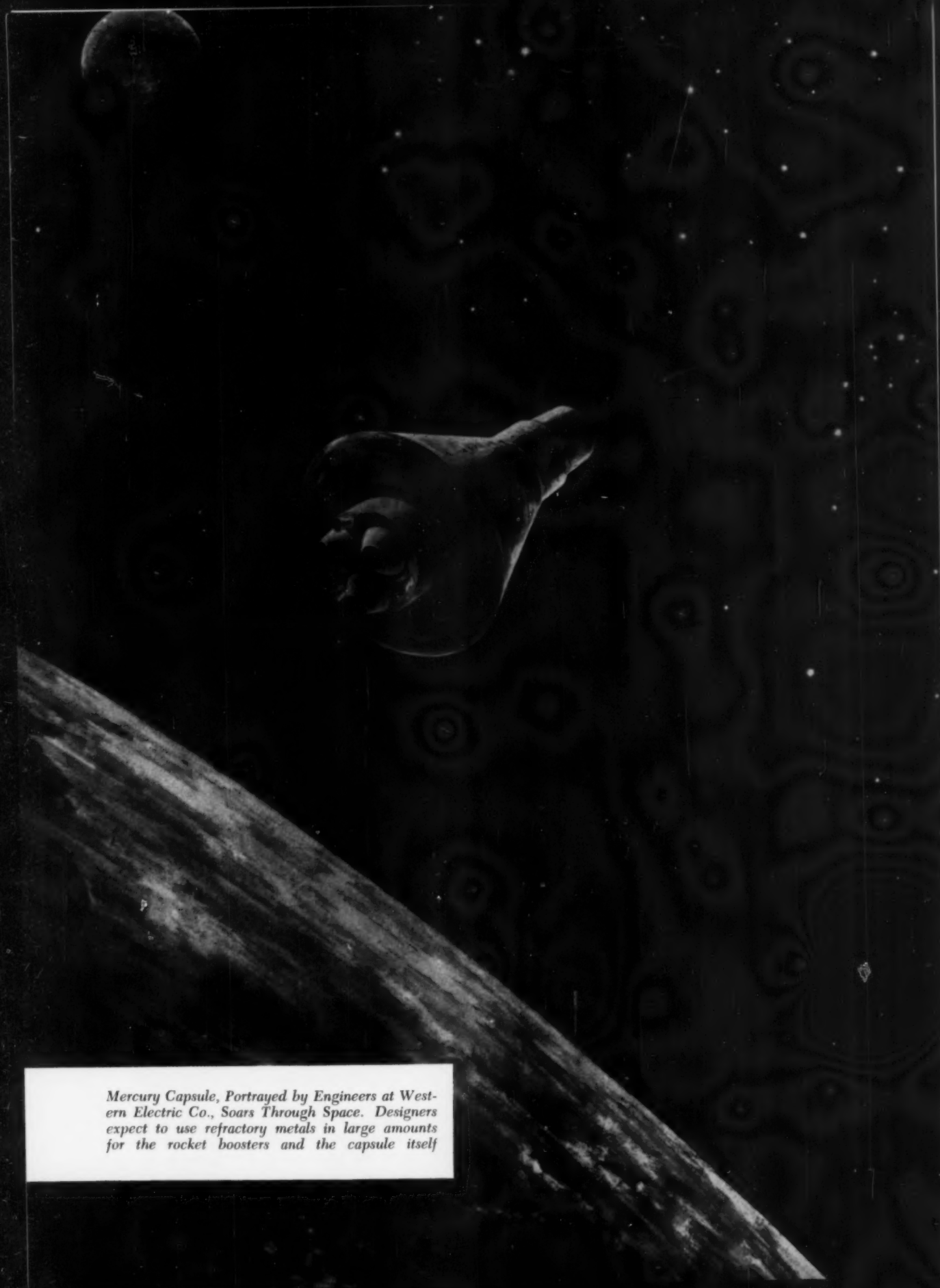
Power Plants Bring Problems

Turning from structural applications, E. Schnetzer (General Electric Co.) surveyed the entire range of current and future propulsion systems, evaluating the needs of each type for refractory metals. Beginning with the T-58 turboshaft engine, he stated that increasing the turbine inlet temperature from 1700 to 2500° F. would reduce the weight from 0.25 lb. per hp. to 0.1 lb. per hp., and reduce specific fuel consumption from 0.70 lb. per hp. per hr. to 0.5 lb. per hp. per hr. A similar rise in turbine inlet temperature would double the thrust of the J-79 turbojet engine at Mach 2.5, improve its fuel economy, and reduce its specific weight from 0.33 to 0.1 lb. per lb. thrust.

Parallel improvements could be realized in the reheat version of the J-79, in ramjets and in turbojet ramjets if refractory metals were available. However, so far, it has not been possible to use any refractory metals in these systems because of their low oxidation resistance. Extensive experiments aimed at introducing molybdenum (and, more recently, columbium) turbine buckets have not yet been successful because of shortcomings in coating techniques.

Rockets powered by liquid propellants have made use of regenerative cooling of nonrefractory materials to handle combustion temperatures in excess of 5500° F. Some consideration is being given to the use of refractory metals in nozzle skirts, however. This may pay off in weight savings or engine efficiency. If so, refractory metals will probably be used for many such parts in the future.

Since regenerative cooling cannot be used in solid-propellant rockets, designers have been forced to employ refractory metals for nozzle liners. Molybdenum, for example, is used in nozzles and jetevators of the Polaris, and tungsten and tantalum are being considered



Mercury Capsule, Portrayed by Engineers at Western Electric Co., Soars Through Space. Designers expect to use refractory metals in large amounts for the rocket boosters and the capsule itself

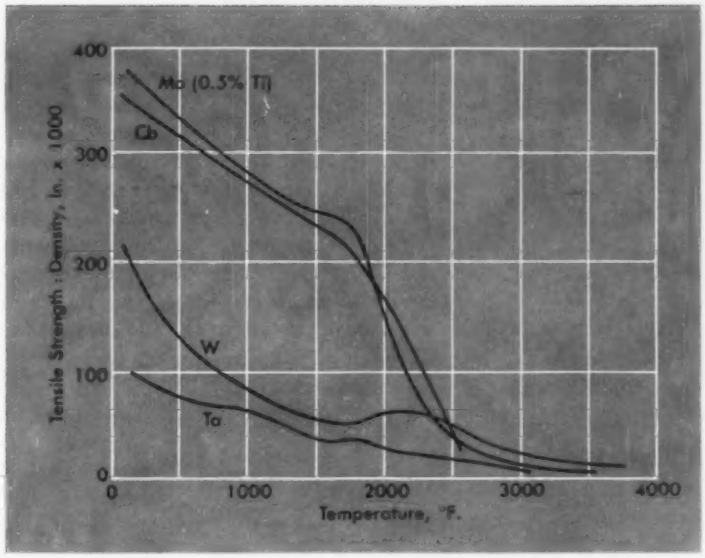


Fig. 2 — Four Refractory Metals Compared as to Strength-to-Density Ratios. Judging from this, only tungsten and, to a lesser extent, molybdenum and tantalum, can be used when temperatures above 2500° F. must be considered

for other parts in the nozzle area. Many of the current applications use forgings, but as size increases, high-quality sheet will be an absolute necessity if the cost of initial purchase and machining is to be lowered.

It can also be foreseen that it will not suffice merely to use materials which will withstand the high temperatures. Even today, some experimental solid propellants cannot be used for lack of a nozzle material, and it seems apparent that ablation or film cooling techniques will have to be developed. Exhaust flames, now relatively inert with respect to refractory metals, will become more oxidizing; this will absolutely require some very efficient protective coating to prevent erosion.

Looking forward, the next major step in rocketry development will be the heat-transfer nuclear rocket. As Fig. 4 shows, the propellant in this system, liquid hydrogen or helium, is pumped through the nozzle lining (for regenerative cooling) and then into a nuclear reactor where it is heated to 3500 to 6000° F. Rockets powered in this manner could attain velocities two to three times as high (and specific impulses one and one-half to three times as high) as chemical rockets. Even with regenerative cooling, high-strength refractory metals will be

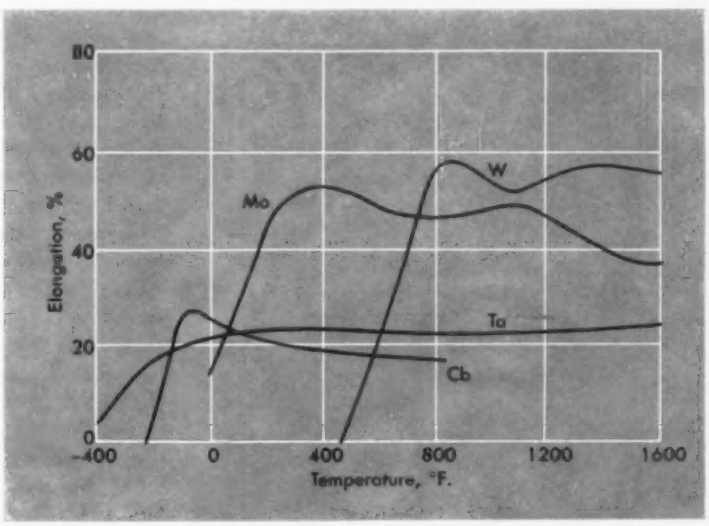


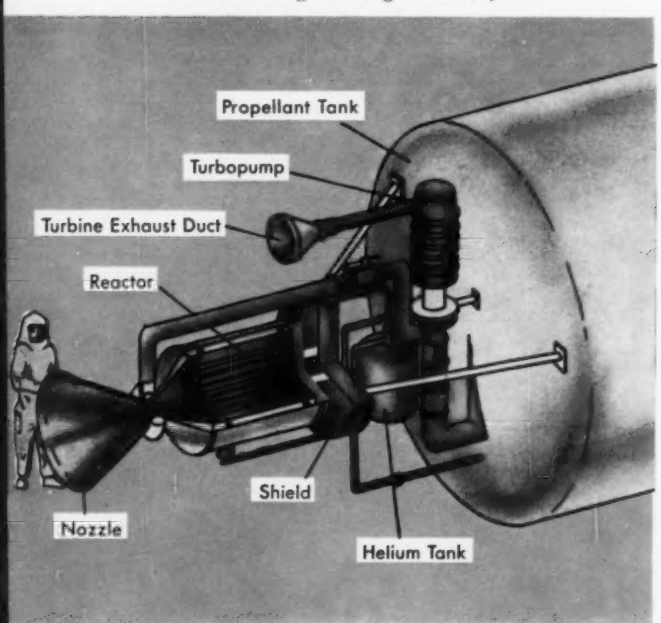
Fig. 3 — How Ductility Varies With Temperature for Four Refractory Metals. Tungsten must be formed while hot and molybdenum may also offer trouble, but columbium and tantalum should form satisfactorily at room temperatures

required to line the nozzle throat. They will also be needed for nuclear fuel containment and reactor structure. However, the inert or reducing atmospheres will make protective coatings unnecessary. First applications (expected about 1970) will probably operate on gas at 3500° F. with a 750-sec. specific impulse and thrust-to-engine weight ratios of about 12. By 1980, we can expect such systems to have advanced to 6000° F. gas temperature, a 1200-sec. specific impulse and thrust-to-engine weight ratios of nearly 50. The 1,000,000-lb. thrust of this engine would be sufficient to put a 150,000-lb. payload in an orbit 300 miles high. For comparison, a 6,000,000-lb. thrust, three-stage chemical rocket would be required for the same job.

Beyond the nuclear rocket are two systems based upon electrical propulsion – plasma jets and cesium ion rockets. In the former, specific impulses of 1000 to 8000 sec. will be achieved with operating temperatures from 6000 to 12,000° F. Regenerative cooling and refractory metals will be used in electrodes and nozzles. The cesium ion rocket will attain specific impulses of 2000 to 20,000 sec. with operating temperatures of only 3000 to 4000° F. However, regenerative cooling cannot be employed; this will make refractory metals necessary for high-temperature components.

Also, both types of rockets will consume large amounts of electric power. The nuclear turbogenerator power systems being designed for them will employ refractory metals in the reactors and turbines, both of which will operate at 1700 to 2000° F.

Fig. 4 – A Nuclear Rocket System. The propellant, liquid hydrogen or helium, travels through and cools the chamber lining; then it is heated to the 3500 to 6000° F. range. Thrust may vary from 60,000 to 1,000,000 lb.; the specific impulse, from 750 to 1200 sec.; and the thrust-to-engine weight ratio, from 12 to 50



Availability and Need

The need for refractory metals in structures and power plants of air and space vehicles is obvious from the above. However, the amount needed is quite limited, both in number of specific items and in aggregate tonnage. Probably the total yearly requirements will be about 500 tons – and this amount is but 5% of the consumption of antimony in this country. Studies of the availability of raw materials have come up with a reassuring answer. As much as 10,000 tons more than current production of tungsten, molybdenum and columbium could be made available. From 100 to 1000 tons of tantalum, and about 100 tons of rhenium, could be produced above present requirements.

Availability of satisfactory mill products is another story. Production is small, quality is variable, and sizes and tolerances are inadequate. Forgings cost from about $15 per lb. for molybdenum to $100 per lb. for tungsten; sheet ranges from $25 to $50 per lb. for molybdenum to $100 per lb. and $200 per lb. for columbium and tungsten, respectively.

Recognizing that the industrial availability of acceptable mill products would lag behind the need, the Department of Defense established the Refractory Metals Sheet Rolling Program. J. R. Lane of Materials Advisory Board, the program monitor, stated that the objective was to develop the technical information necessary to produce (and to evaluate) high-quality sheet metal which would have consistent properties. Six subpanels have been created. They are responsible, respectively, for alloy requirements, coating, joining, quality standards, test methods and analytical problems. In Phase I, researchers will determine the significant variables incident to production and evaluation of high-quality sheet. Phase II provides for determination of mechanical properties and other design criteria. Finally, in Phase III, fabrication and assembly techniques

will be developed, and full-scale assemblies, will be built.

Work thus far has been devoted to the first phase. Universal-Cyclops Steel Co. has a contract to produce 8000 lb. of high-quality molybdenum sheet, up to 36 × 96 in. Also Crucible Steel Co. of America is to produce defect-free, high-formability columbium sheet with 100,000 psi. ultimate tensile strength, and Sylvania Electric Products Inc. is working on the production of molybdenum alloy sheet by the powder process. Two research-oriented contracts are held by Armour Research Foundation and Wah Chang Corp. The first contract specifies investigation of the feasibility of producing molybdenum by the Kroll process and of consolidating resultant sponge or powder by hot extrusion. Meanwhile, the influence of impurities on properties of molybdenum sheet is being studied by Wah Chang. Contracts for production of tungsten sheet are in the proposal stage.

Fig. 5 – Rocket Nozzle Forged From Tungsten Ingot. This 8-in. nozzle was forged by Ladish Pacific Co., from an ingot, 3½ in. in diameter, which in turn was made by an electron beam process developed by Stauffer-Temescal

Consolidation and Primary Working

Both melting and powder metallurgy techniques are now being used to consolidate refractory metals, according to E. E. Reynolds (Allegheny Ludlum Steel Corp.), who pointed out that all melting and sintering methods use inert atmosphere or vacuum to minimize reactions with oxygen, nitrogen and hydrogen. Melting processes employed are consumable electrode, nonconsumable electrode, electron beam, zone, skull, levitation and induction. Variations among powder techniques are mainly in the manufacture of the green compacts; these are made by mechanical pressing, hydraulic pressing, isostatic pressing, explosive compacting, rolling, and slip casting.

The metallurgical characteristics of refractory metals impose severe restrictions on the equipment and practices used for processing them into mill products. Their high recrystallization temperatures (for example, 1830° F. – or 1000° C. – for molybdenum and 2370° F. – or 1300° C. – for tungsten) dictate hot working at temperatures above the capability of most mill heating equipment. Because of their inherent strength, these metals have great resistance to deformation, even at hot working temperatures and, as stated before, cold working is difficult on those alloys having ductile-to-brittle transition temperatures above room temperature. Generally, annealing is necessary. This operation, as well as heating for hot working, must be performed in inert atmosphere or vacuum because of the extremely poor resistance of refractory metals to oxidation. Although their high thermal conductivities allow shorter heating times, cooling during hot working is also rapid. Much progress in combating these restrictions is expected at the In-Fab* facility recently completed by Universal-Cyclops. Here, in an 80 × 40-ft. room filled with 99.995% pure argon, personnel clad in space suits will operate a rolling mill 36 in. wide, a 15,000-ft-lb. impacter, a shear and necessary complementary vacuum furnaces.

Forging Used Widely

In manufacturing parts from refractory metal mill products, forging is being used extensively as an intermediate operation. According to R. P. Daykin (Ladish Co.), the more difficult-to-forge refractory metals, tungsten, molybdenum and columbium, are about as stiff as A-286, but not as stiff as René 41. This statement applies to forging in the hot-cold work range to secure increased mechanical properties. (In the true hot working range, refractory metals are mushier than carbon steel.) Sufficient plasticity is available so that existing forging equipment is powerful enough. Molybdenum forgings, for example, can be made in about the same shapes as titanium forgings. More specifically, web thickness limitations would be ⅜ in. or ½ in. in a large, relatively simple forging of approxi-

*See Technical News in Brief, *Metal Progress*, July 1960, p. 65.

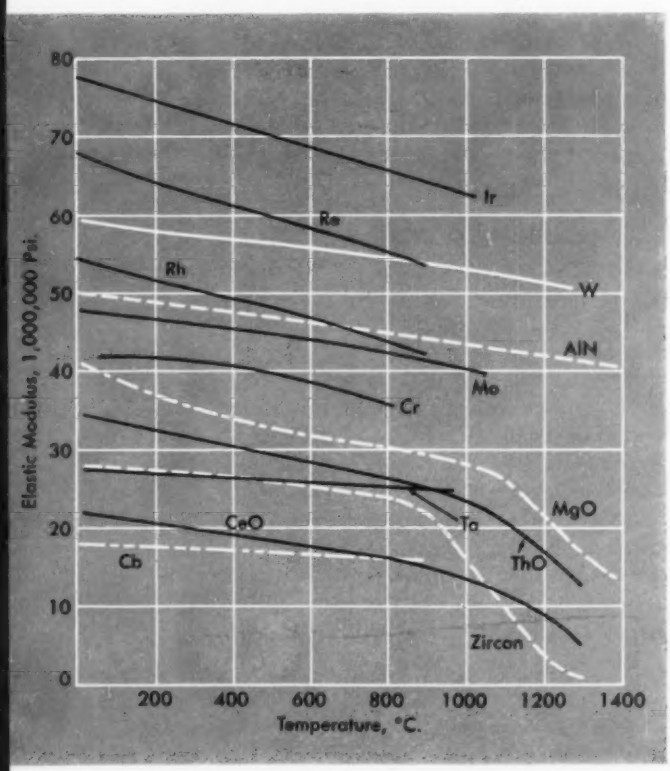
mately 150 sq.in. surface area, providing there were not too many ribs and bosses.

The most severe limitation on size of forgings is the size of billets available. Rolled ring forgings (molybdenum) for nozzles have been made in the 14 to 15-in. diameter range. Closed die forgings of tungsten (see Fig. 5) haven't gone beyond 8½ in. diameter (nozzle inserts) to date, but approximate shapes have been forged in the 10 to 12-in. diameter range. On the other hand, closed die forgings weighing up to 2500 lb. have been produced from 15-in. diameter ingots of 1% zirconium-columbium alloy.

Forging costs are high but not unreasonably so. For example, the molybdenum turbine bucket forgings for the J-47 hot rod engine (which weighed about 2 lb. each) were priced at $125 per lb. After machining, each bucket weighed slightly less than 1 lb.

Although conventional hammer and press equipment is used for forging, higher temperature heating equipment (furnace or induction, 3400° F. capability) with protective atmosphere is necessary. Normally, tungsten forging starts at 3000° F. As reduction progresses and the recrystallization temperature decreases, the working temperature is lowered to maintain the increased properties resulting from hot-cold working. Oxidation during forging is not a serious problem on tungsten and molybdenum. (As a matter of fact, the oxide serves as a rather effective lubricant.) Proprietary coatings have been used quite successfully in protecting columbium and tantalum during forging.

Fig. 6 – Effect of Temperature on Elastic Modulus of Some Refractory Materials



Forming Not Difficult

As with forging, forming of refractory metal sheet is limited more by available size than by equipment capabilities. Experience at Aerojet-General, related by R. A. Perkins, has not indicated any limitations in forming molybdenum and tungsten on conventional equipment. Of course, any severe forming operations must be performed well above the ductile-to-brittle transition temperature; therefore, some heating equipment is required. Oxy-acetylene torches suffice for many operations, surface contamination being ground or pickled off later. Metal losses are minor, and protective coatings are unwarranted because parts are surrounded during forming by an atmosphere of the volatile oxide.

At the proper temperatures, all conventional forming techniques can be used, according to A. B. Michael (Fansteel Metallurgical Corp.). Tungsten sheet, for instance, can be drawn into cups (2½ in. deep × 4 in. I.D. × 1/16 in. wall) at 2370 to 2550° F. (1300 to 1400° C.) and flow-turned to reductions of 0.030 in. to 0.060 in. per pass at 2200° F. Cups as large as 18 in. in diameter can be deep drawn, but 9 in. O.D. is the largest made to date because larger tungsten sheets are not available.

In addition to stock size limitations, forming operations are currently handicapped because quality is not uniform from supplier to supplier and from lot to lot. Extensive standardization work will be required before large-scale production is practical. As an example of how variations in chemistry and prior history affect formability, F 48 columbium alloy can be successfully formed at −100° F. when carbon content is 0.03% or lower, but with 0.05% to 0.06% carbon content, the transition temperature is about 300° F. Before columbium and molybdenum alloy sheet are severely formed, it is often necessary to remove 0.003 to 0.005 in. of surface contamination by sanding with 120-grit belts to prevent cracking.

Welding and Brazing

Fusion welding by the inert-gas, shielded-arc process is the most common method of joining refractory metal parts. However, according to R. G. Frank (General Electric Co.), electron beam welding appears likely to become the predominant method in the future because it offers greater penetration-to-width and depth-to-width ratios with narrower heat-affected zones. In addition, the welds have better ductility because they are purified and degassed by the vacuum. Electron beam welds also have a finer grain size, another characteristic which improves ductility.

Welds in tantalum, columbium, and columbium alloys are quite ductile, while those in tungsten, molybdenum and molybdenum alloys are quite brittle, although only slightly less ductile than the base metal. However, in spite of this brittleness at room temperature they possess usable strength and are relatively ductile above the transition temperature. Some thought is being given to employing hot working (for example, planishing, of the weld bead and recrystallized heat-affected zone) to restore basic sheet properties.

Another approach to the brittleness problem (related by E. D. Weisert, Marquardt Corp.), has been development of a 35 at.% rhenium-molybdenum filler wire for welding Mo (0.5% Ti) sheet. Weldments so produced have proved stronger than the base metal and can withstand an 80° bend around a radius equal to the thickness at room temperature. Unfortunately, the weld beads are susceptible to rapid, preferential attack when the conventional oxidation-protective coating is applied. The embrittlement which results probably occurs because sigma phase may form when the coating is heat treated. Reducing the rhenium content to 25 at.% may eliminate these deficiencies.

Contamination is one of the major factors which must be controlled in welding molybdenum. If contaminant level of the bead is allowed to go as high as 1000 ppm., it is fairly certain that the weld will not be sound. Instead, it will probably exhibit center-bead or some other type of cracking. If contamination is held to 70 ppm., however, welds will probably be sound. To some extent, this characteristic is related to grain size because contaminant compounds tend to congregate in grain boundaries. Hence, in large-grained material with its lower grain-boundary area, the higher concentration of contaminant compounds in boundaries weakens them.

In welding columbium alloys, it is important to control microstructure by post heat treatment. For example, heat treatment at 1950° F. after welding produced brittle welds in Fansteel 82 alloy, but interposing an anneal at 2100 to 2200° F. between welding and the 1950° F. treatment produced ductile welds. Similarly, welds in F 48 alloy as welded will only withstand about a 10° bend. However, welds annealed at 2500° F. can be bent 105° around a radius equal to three times the thickness.

Refractory metals and their alloys can be spot welded to each other and to themselves quite satisfactorily. For example, spot welded structural sandwich panels with tantalum honeycomb core and tungsten face plates are available. Resistance spot brazing, with 0.002-in. tantalum foil between faying surfaces, has also been used successfully. To braze molybdenum and its alloys by conventional techniques, a filler metal of chromium-nickel-palladium alloy has been developed. This has replaced the silicon-boron alloy filler which caused brittle interfaces to form. This problem of brittle interfaces has also plagued attempts to fusion weld refractory metals to nickel alloys; ductile joints can only be made by brazing with a copper-platinum filler alloy.

Failure to specify strain rate when quoting property requirements is an error which has cropped up quite frequently in procurement of refractory metals. Both ultimate strength and elongation are extremely sensitive to strain rate. To illustrate, a molybdenum specimen pulled to failure in 100 sec. or less will show practically no elongation; however, one pulled at 0.005 in. per in. per min. to yield an 0.01 to 0.03 in. per min. crosshead speed to failure (roughly 600 sec. total) will elongate around 42%. Slower rates of straining do not appear to have any further effect.

Refractory Nonmetallics

In comparing refractory metals with other refractory materials, R. I. Jaffee (Battelle Memorial Institute) pointed out that the nonmetallics suffer severely because hot working processes for consolidation and grain refinement are lacking. Therefore, elimination of porosity depends solely on diffusion during sintering, and it is rarely possible to achieve theoretical density. Since porosity has a potent effect on load carrying capacity *(Continued on p. 136)*

New

Progress in High-Temperature Materials

Device Used at Battelle Memorial Institute for Determining Mechanical Properties of Ceramics Between 2000 and 4000° F. The apparatus consists of a loading device, vacuum furnace, temperature and strain-measuring setups, and a power source

AT LONG LAST, metallurgical theory and testing methods are being applied to the study of ceramics – this was the significant feature of the Conference on the Mechanical Properties of Engineering Ceramics held recently at North Carolina State College. Sponsored jointly by the Office of Ordnance Research, U.S. Army, and the School of Engineering at North Carolina State, this conference attracted some 200 key scientists and engineers from laboratories throughout the United States, and from several foreign countries as well. At this meeting, speakers repeatedly stressed their intention to develop direct correlations between mechanical properties of ceramic materials and their internal structure and constitution. While this approach has long been applied to the understanding of metals and alloys, its intensive application to ceramics has been more recent.

Virtually all of the papers presented at this meeting can be classed in three categories: *(a)* fundamentals of structure and constitution as related to properties; *(b)* development of special tests for correlation of structure and properties; *(c)* evaluation of specific materials.

In the keynote address, E. R. Parker (University of California) pointed out that metallurgists as well as ceramists have been vitally concerned with brittle fracture. This concern has led investigators of metals to employ ceramic materials in their studies since such materials are more susceptible to brittle behavior than metals. Certain ceramics are also more simple in their structure than metals.

Science of Ceramics Takes Hold

*Reported by W. W. AUSTIN**

Testing techniques pioneered by metals engineers are now being widely used to evaluate ceramic materials. At a recent conference in North Carolina, researchers presented significant information relating the mechanical behavior of ceramics to their fundamental structures. One result: Ceramics which are reasonably resistant to impact and heat up to 5000° F. appear to be in the offing. (Q-general, M-general; NM-f)

As a natural outgrowth, researchers have not only gained a better understanding of brittle behavior, but have also increasingly realized that all materials follow the same fundamental laws in their physical and mechanical behavior. Thus, solid-state research is now aimed at improving the knowledge of how and why materials behave as they do, their metallic or nonmetallic characteristics notwithstanding.

Empirical methods are no longer adequate to provide solutions for complex materials problems, basic research now being the only sure path to advancement. Although it is now possible, with the concepts of quantum mechanics and solid-state physics, to devise quantitative theories which relate structure and constitution to properties, this field of knowledge is by no means complete. We cannot yet predict nor compute in a precise manner the properties of materials from fundamental data. Nevertheless, much has been learned, and such factors as the essential role of lattice defects in determining mechanical behavior are now well established. Today such types of lattice imperfections as dislocations, vacant lattice sites, interstitial atoms, electrons and holes, and "phonons"† and "excitons"† are being explored.

*Head, Department of Mineral Industries, North Carolina State College, Raleigh, N.C. In general, individual papers and authors are not identified since conference proceedings will be published in book form.

†Imperfections associated with or resulting from localized energy gradients in the lattice.

Fundamentals of Structure

Of all the fundamental concepts involved in the study of mechanical behavior of materials, dislocation theory is perhaps the most universally applicable. Two papers in the conference described current research which was specifically concerned with dislocations in ceramic materials; several others, as well, were directly concerned with mechanical behavior as influenced by dislocations. For example, one investigation employed electron microscopy to examine and identify characteristic banded structures resulting from dislocation movements in single crystals of talc. Complex dislocation nets, arising from interaction between these bands, are also under study in relation to the observed mechanical behavior of talc crystals.

A new technique for evaluating dislocation behavior in ionic crystals under dynamic conditions has been perfected recently. To do this, a small cylindrical specimen crystal is subjected to cyclic loads by bending while an a-c. signal is passed through it. Oscilloscope studies of the resulting modified signal have revealed significant relationships to structural characteristics such as vacancy migration and dislocation movement. These features can be directly correlated with deformation of the specimen.

Recently, major improvements in research techniques and tools have led to many important contributions on the relation of engineering properties of ceramics to their microstructure. Here, the methods of physical metallurgy and

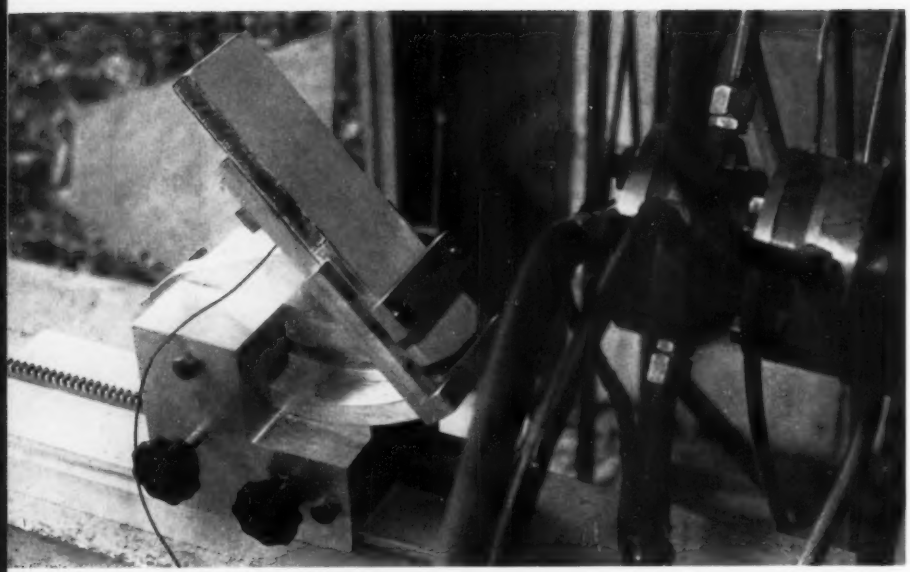


Fig. 1—Hydrogen-Oxygen Rocket Motor in Position to Test Ceramic Panel. Up to 5000° F. is reached during test

metallography are being applied to ceramic materials to good advantage. The electron microscope has revealed grain and subgrain boundaries in ionic solids, and researchers are now exploring the segregation of impurity atoms at these locations. Microhardness tests are extensively used along with the microprobe (an instrument that can provide accurate quantitative analyses of areas or particles as small as one micron in diameter).

Some Ceramics Are Ductile

Also reviewed at the conference was an important and widely acclaimed series of investigations on ductility in certain ionic solids. According to recent findings, many ceramic materials with sodium chloride or cesium chloride structures are substantially ductile – at least when they are in a state of high purity and tested in the form of single crystals. However, when freshly cleaved surfaces are contaminated by exposure to the atmosphere, the observed ductility in such crystals as sodium chloride, potassium chloride and potassium bromide is seriously impaired. On the other hand, single crystals of magnesium oxide of commercial purity can be deformed plastically at room temperature. In the latter instance, some specimens deformed as much as 20% before failing. Further study of magnesium oxide of commercial purity has revealed that dislocations accumulate at slipband intersections; these are responsible for its normal brittle behavior.

In another investigation of the plasticity of single crystals of magnesium oxide, the effects of "doping" with selected impurities are under study. The addition of 0.7% Cr_2O_3 increases the room-temperature compressive yield strength of magnesium oxide by a factor of three or four times – or from 12 to 14 kg. per sq.mm. (17,100 to 19,900 psi.) in pure MgO to 30 to 45 kg. per sq.mm. (42,600 to 64,100 psi.) in doped MgO. Such specimens, however, undergo very little plastic flow prior to fracture. Smaller additions (0.2%) of Cr_2O_3, or as little as 0.025% NiO, will increase the compressive strength while maintaining substantial over-all plasticity in the crystal.

Some of the doped single crystals are cloudy; the cause is unidentified as yet. Such crystals can be deformed plastically up to 10% before fracture. Researchers have postulated that the cloudiness is associated with minute voids which interfere with the normal propagation of fracture. Parallel studies reveal that single crystals of calcium oxide containing on the order of 0.1 to 1.0% MgO also undergo 8 to 10% plastic deformation before failing.

Special Test Methods

To aid in this fundamental work, several novel test methods have been devised. These special tests are the natural outgrowth of work with minute specimens (frequently single crystals), and they often incorporate ingenious electronic circuitry with precise electrical measure-

ments that can be correlated with properties.

Such an instance is illustrated by a bend-test furnace with atmosphere control, and an electronically actuated strain recorder. This equipment has been used for measuring the modulus of rupture of beryllium oxide at 1760° C. (3200° F.). In operation, small cylindrical test specimens are subjected to three-point loading in a helium atmosphere. Preliminary results indicate that the properties of hot pressed specimens are better than those of either cold pressed or slip-cast specimens.

In a related investigation, similar equipment has been used to evaluate creep at 1000 to 1200° C. (1830 to 2200° F.) in synthetic sapphire (alpha Al_2O_3). Specimens (0.1 in. in diameter by 3 in. long) are stressed in three-point loading while being maintained at the test temperature. In this instance, the electrically measured creep rates reveal a second power dependence of creep rate upon stress intensity.

In still another study, engineers devised equipment to evaluate the performance of ceramic materials under conditions of aerodynamic heating in space vehicles and missiles. Flat plate specimens are exposed to the blast of a small rocket motor simulating Mach 4 or 5 velocities. (Figure 1 illustrates the setup.) Temperatures rise as high as 2760° C. (5000° F.). As a result of these tests, a new material, slip-cast fused silica, has been proven superior to sintered Al_2O_3 and "Pyroceram"*.

Metallographic Techniques

Such well-known metallurgical tools as microhardness measurements and special metallographic techniques are now playing important roles in several highly significant programs. In one such investigation, thermal etching – a technique much like heat tinting in metallography – is being applied to a fundamental study of Al_2O_3 in the form of synthetic sapphire. First, a polished specimen is heated in air to 1900° C. (3450° F.); this develops a fine microscale relief which reveals the existence of dislocations, subgrain boundaries, growth layers, and plastically deformed regions. Knoop microhardness surveys of these areas show that the crystals are markedly anisotropic. In certain directions, appreciable plastic flow is evidenced by the appearance of slip lines adjacent to the microhardness indentations. Severe fractures, with no detectable plasticity, are also observed

*A type of glass almost completely insensitive to thermal shock.

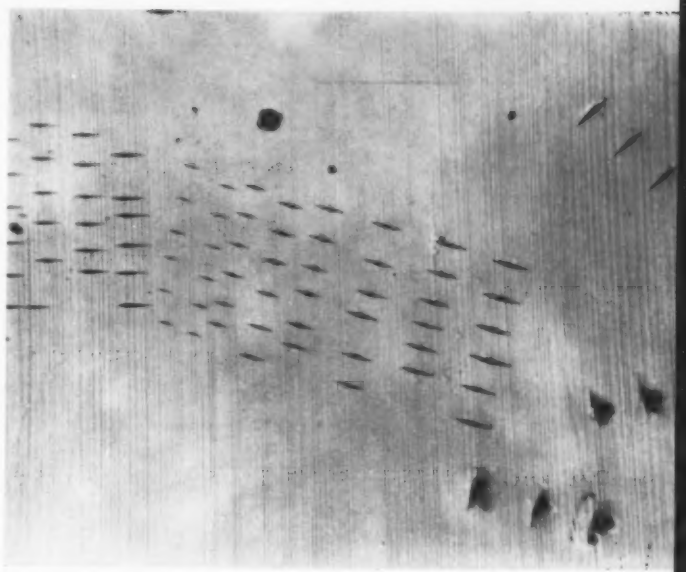


Fig. 2 – Microhardness Tests on a Single Crystal of Sapphire (Al_2O_3 Plus Approximately 0.05% Total Impurities, Principally Iron and Nickel). Patterns of indentations show anisotropic behavior as a function of orientation of Knoop indenter with respect to striations developed by thermal etching. Magnification 150 ×, thermally etched in air at 1900° C. (3450° F.)

Fig. 3 – Microhardness Tests on a Basal Plane of a Single Crystal of Sapphire. Striations developed by thermal etching are parallel to the 1230 direction and irregular contours result from imperfection concentrations not fully identified. Magnification 1000 ×, thermally etched at 1900° C. (3450° F.) in air

Fig. 4 – Throat Dimensions of Graphite Rocket Nozzle Are Checked

at indentations having different orientations in the same crystal. Figures 2 and 3 illustrate these effects.

Applying X-Ray Analysis

In another test method, X-ray analysis is applied to evaluate internal stresses in polyphase ceramic systems. Of the many factors affecting the properties of polyphase ceramic bodies, the internal stresses that result from a mismatch between thermal expansion coefficients are most difficult to handle quantitatively. In this investigation, back reflection X-ray diffraction is employed to detect internal strain in the Al_2O_3 phase of a system containing Al_2O_3 and a glassy phase. Internal stresses are determined in terms of the shift in intensity peaks resulting from heterogeneous thermal contraction between the two phases. Selection of several specific glassy phases with expansion coefficients above and below that of Al_2O_3 permits internal stresses to be thoroughly studied at various intensities.

Evaluation of Specific Materials

Among the available materials for applications in space technology, ceramics occupy an enviable position. With recent notable advances in ductile ceramics, these materials offer potential combinations of virtually all of the engineering properties needed for structural applications at elevated temperatures. Recent research on specific ceramic materials has been aimed at evaluating these properties more accurately, and also controlling more effectively the processes for maintaining them at desired levels.

Illustrative of this type of research is the current work on graphite, one of the older nonmetallic structural materials. (Figure 4 shows a rocket nozzle made of graphite.) With this material, workers are conducting exhaustive studies of stress-strain, creep, and relaxation properties at temperatures up to 2800° C. (5070° F.) In one study, torsional shear properties of conventional molded graphite are being correlated with strain, stress-rate, strain history, and grain orientation. In other investigations, a new form of graphite is being studied. Termed "pyrolytic graphite", it is produced by pyrolytic decomposition of hydrocarbon gases at high temperatures. In comparison to conventional molded graphite, pyrolytic graphite exhibits definitely superior high-temperature properties, approaching those of single-crystal graphite in many respects.

Also being considered as a potential structural material is aluminum oxide, a material that has received major attention in recent investigations. Here is another illustration in which metallurgical research techniques are being used with ceramic materials. Researchers have adapted the *(Continued on p. 146)*

Forming Galvanized Sheet Steel

*By PAUL G. NELSON**

Galvanized sheet – either differentially coated or protected only on one side – is receiving a great deal of attention because of its potential in auto bodies. Preliminary experience indicates that it can be formed as readily as uncoated steel but not with the same tooling. (G-general, F29s; ST, 8-65, *Zn*)

IN RECENT YEARS, the steel mills have made great strides in improving the adherence of zinc coatings applied to galvanized sheets. It is possible to form parts that could not have been made previously without loss of corrosion resistance in severely formed areas.

These new galvanized steel sheets are generally produced from cold rolled coils that are annealed under controlled atmosphere conditions which prevent oxidation. After annealing, the coils are passed continuously through a molten zinc bath where exit rolls control thickness and uniformity of coating. The galvanized coil may then be supplied as coil or sheared into sheets.

Properties of Galvanized Sheet

Galvanized sheets are supplied in the same grades as uncoated or "black" steel – commercial quality, drawing quality and aluminum killed. They may also be supplied annealed or annealed and temper rolled. Temper rolling must be done after galvanizing if stretcher strain markings are to be avoided. Some manufacturers have facilities for galvanizing box-annealed sheets. Box-annealed sheets generally are softer and somewhat more ductile than equivalent grades of continuous-annealed products.

Table 1 shows typical mechanical properties of continuous-annealed compared to box-annealed galvanized sheets. For comparison, properties of typical box-annealed "black" sheets are also listed.

These results show that yield point and tensile strength of continuous-annealed galvanized steel are consistently higher than the equivalent values of regular grades of uncoated steel. Values for elongation in 2 in. are also generally lower than those of "black" steel. Elongation to maximum load or uniform elongation values compare more favorably with uncoated steel. This behavior is characteristic of continuous-annealed steel.

Selecting the Proper Grade

Galvanized steel grades can be selected by a method similar to that outlined for uncoated

*Superintendent, Production Laboratory, Budd Co., Philadelphia.

Table I – Properties of Galvanized and Uncoated Sheets (0.035 In. Thick)

Sheet*	Yield Point	Tensile Strength	Elongation in 2 In.	Uniform Elongation	Rockwell Hardness	Olsen Cup
BA galvanized, KS	28,000 psi.	46,000 psi.	40%	22%	B-47	0.385 in.
CA galvanized, CQ	42,000	52,000	30	18	58	0.370
CA galvanized, DQ	40,000	50,000	32	20	56	0.375
CA galvanized, KS	40,000	50,000	37	24	58	0.390
BA black, CQ	33,000	46,000	38	18	46	0.390
BA black, DQ	28,000	45,000	42	22	43	0.390
BA black, KS	26,000	44,000	42	25	41	0.400

*BA—box annealed; CA—continuous annealed; CQ—commercial quality; DQ—drawing quality; KS—killed steel.

steel. Table II indicates probable choices of grade for various classes of stampings. Continuous-annealed killed steel is considerably inferior to box-annealed killed steel sheet. The continuous-annealed killed sheet has finer grain size, a less favorable equiaxed grain shape, and is more susceptible to quench aging than box-annealed steel. Because of these factors, continuous-annealed killed steel does not offer much advantage over rimmed steel in most forming operations. Conversely, galvanized box-annealed killed steel has better formability than other grades.

Some of the disadvantages of poorer mechanical properties of galvanized steel are offset by the lower coefficient of friction of the zinc coating. Where actual drawing or a combination of drawing and stretching is done, greater reductions are possible with galvanized steel than with uncoated steel of similar properties.

Table II – Severity Classification for Parts Made From Galvanized Steel

Severity* Class	Exposed Part†	Unexposed Part†
1	Commercial quality CA or BA	Commercial quality CA or BA
2	Commercial quality CA or BA	Commercial quality CA or BA
3	Drawing quality CA or BA	Commercial quality CA or BA
4	Killed steel CA or BA	Killed steel CA or BA
5K	Killed steel BA	Killed steel BA

*Higher numbers indicate greater severity. See 1955 A.S.M. Metals Handbook Supplement, Table I, p. 2, for additional information. (Also in *Metal Progress*, Aug. 15, 1955, p. 2).

†CA—continuous annealed; BA—box annealed.

How to Get a Good Surface

Prior to its use in the automotive industry, galvanized steel rarely was required to be free from stretcher-strain markings after forming. Usual mill practice for this steel did not require temper rolling, an operation normally applied on uncoated steel for exposed parts. Instead of temper rolling, it has been common mill practice to roller level. Roller leveling eliminates the fluting which occurs when parts such as pipe are rolled. However, it causes numerous small coil breaks perpendicular to the rolling direction. These coil breaks are not objectionable in most galvanized steel parts, but when aging occurs, they cause nonuniform stretching in the rolling direction in subsequent forming operations. The nonuniform nature of this deformation reduces the elongation that can be obtained. Also, the rough appearance is objectionable for exposed parts.

For most automotive parts the type of forming will not require antifluting characteristics. Therefore, roller leveling at the mill may be eliminated. It should also be omitted where parts must be free of stretcher strains after forming. However, steel for exposed parts must be temper rolled at the mill after being galvanized. Because some aging with accompanying propensity to stretcher strain will occur even in killed steel, roller leveling is usually required on steel used for exposed parts. This must be done in the fabricator's plant shortly before forming rather than at the steel mill.

Flaking Is a Problem

A common problem encountered in forming of galvanized sheet is flaking. Flaking occurs

in operations such as drawing and channel forming where severe wiping occurs. It is usually not severe enough to cause loss of corrosion resistance. Nevertheless, the flaked zinc must be removed from recesses and other interior parts of dies. If allowed to accumulate, it will result in excessive loads being built up in dies and presses with possible breakage. Lubrication is usually less troublesome with galvanized steel than uncoated because the zinc coating generally prevents die "pickup". Straight mineral oils are satisfactory lubricants.

New Trends in Galvanized Sheet

Some galvanized sheet is being supplied in differentially coated form. This steel is processed by a method similar to that used on regular galvanized steel but most of the zinc is wiped from one surface as it emerges from the galvanizing pot. The sheet has a zinc coating of about 0.60 oz. per sq.ft. on one side and about 0.10 oz. per sq.ft. on the other. The principal purpose of thinner coating is to provide better spot welding characteristics. Forming properties of the differentially coated product are equivalent to those of regular coated steel if other mill processing methods are similar.

Other developments are sheet which is galvanized only on one side and nonaging galvanized sheet steels. A sheet with no zinc on one side would have welding and painting advantages. Nonaging steel will be needed for severely formed parts. However, the most widely used grade will probably be commercial-quality continuous-annealed galvanized sheet since drawing-quality and killed steel will not offer the same advantages as those found in uncoated sheet. The vastly different properties of this product will require modifications of tools if satisfactory parts are to be made. It appears highly unlikely that galvanized sheets and uncoated sheets may be formed interchangeably on the same tools, but with proper tooling, galvanized steel will probably be no more difficult to form than uncoated steel.

Formability Tests for Sheet Metal

*By TOM BISHOP**

A cheap and rapid test which can be performed in the shop and which duplicates shop conditions is still unknown. The best that our present laboratory tests can do is to classify samples as to grades or quality levels. (Q23q, 1-54; 4-53)

AN INTERNATIONAL GROUP of metallurgists and testing engineers met in Paris late in May, amid the debris of the Summit Conference, to discuss the shaping of sheet metal and tests to determine formability. It was attended by over 200 men coming from 15 countries. The colloquium was organized jointly by the International Deep Drawing Research Group (G. de Witte of Holland, president) and the Société Française de Métallurgie (M. H. de Leiris, president). The first mentioned group,

*Consulting Editor, Metal Progress; member of the firm of John Miles & Partners (London) Ltd., consulting engineers to the metallurgical industries.

founded in 1957, seeks to achieve closer international cooperation in the testing of sheet metal for formability and to arrange faster international standardization of such tests.

Formability

Formability includes only one of the many fields of technological tests dealing with the mechanical behavior of metals. (Among others are strength of boiler steels, brittle fracture of hard metal, and creep.) The one big difference is that the information obtained from formability tests can be compared directly with the performance of the metal *during* its fabrication, whereas other tests are concerned more with application of the metal *after* manufacture. As President de Witte of the Research Group pointed out, formability tests apply to what *will* happen during fabrication, while most other tests apply to what is vaguely feared *might* happen later.

Many metallurgists and sheet-metal users are not satisfied with the testing methods currently available. Some hard-headed production executives wonder if anything has been achieved at all, when they are informed from certain quarters that the original tensile test is very poor in predicting drawability, or (on the other hand) that the old Erichsen or Olsen test may not be considered as a deep drawing test, or that the Rockwell hardness does not say anything essential to performance in the stamping shop. When we look at the actual routine testing program of most producers and users of sheet metal, scarcely any change is observed from the types of tests now in daily use compared with those in decades past. Is there anything wrong with the development of formability tests? It would seem from what was said at the conference that the matter is indeed as difficult as it appears.

Terminology

Accurate definition of terms like formability, drawability, deep drawing capacity, stretchability and ductility are essential before true understanding can be achieved. These words are used in speech and in print as if everyone understands quite clearly what is being spoken about, yet many would be at a loss to give a succinct definition of even one of them. Happily accuracy in terminology is now increasing in technical literature.

One aspect of formability relates to a given job in the press shop; sometimes "specific formability" is used for this.

Another aspect could be called "general formability". Most metals can, in practice, be classified by grading, the higher the grade the more difficult the jobs which can be done on the sheet, so that "general formability" increases with the "grade number". A test which discriminates poorly between a certain set of sheet grades can theoretically be an excellent one with regard to a certain specific formability – and conversely.

The third aspect of the use of such words is neither directly related to the press shop nor to the assessment of grades, but to numerical test values.

Requirements of a Test

A logical approach is to choose a testing method which assesses one different grade of sheet metal as distinctly from another as possible, or which can give maximum information and differentiation about the degree of consistency of a certain sheet quality within one shipment or one grade of sheets. The discriminating power of the testing method must be high, although the variables are such that it is often impossible to compare discriminating power of different criteria in a positive sense. It is of course dangerous to generalize and extrapolate results beyond the limitations of the experiments themselves.

In other words, the actual discriminating power depends on both the test and the sheet characteristics. This shows that one universal method of testing general formability cannot be devised with an adequate discriminating power for all metals, and, at the same time, for a given metal for whatever system of grades. As was observed at the meeting in Paris, this conclusion must be a great relief to manufacturers of testing machines!

It must be decided whether a testing method or numerical value gives either basic or technological information. A fundamental characteristic is defined as one whose values does not depend on the way it has been determined. Thus, many quality factors are not fundamental – yield strength and uniform elongation are examples of this. A fundamental test value does not depend only upon the details of the testing method; the value is also dependent upon the essential characteristics of the material being tested.

Sampling and Interpretation

Another difficult problem before the sheet metal user is that of sampling. How should the inspector take a sample of a shipment so as to be sure that the test result is truly representative of the lot? Is it even permissible to attribute a certain level of quality to a single sheet (inhomogeneity is possible), or has one to accept a mixture of quality levels with a certain average value and statistical spread? The example was quoted in the event that one lot of wide sheets of rimming steel should be used for making thimbles or bathtubs. In the first, the thimbles will consider the sheet as a material consisting of parallel zones of quite different properties, edge to edge, whereas the bathtubs will not. Again, how should one sample in these two instances?

A further problem concerns the interpretation of laboratory results by the press shop. Three possibilities may occur:

1. The pressing runs faultlessly without any difficulty after the first adjustment of the press.
2. Periodic adjustment avoids failures.
3. Failures occur notwithstanding continuous control of the adjustment.

Thus, even the action of the press and the complexity of straining between flat stock and finished part hardly assesses materials in an adequate manner – there is the condition of the machine and the tools, the facilities for adjustment, and the type of lubrication (to mention three factors). Consequently, the results in a press shop tend to lead to a statistical rather than to an incidental type of study.

Cup Forming Tests

Cup forming tests are still very widely used for assessing sheet metal. Many of the contributions at the Paris colloquium endeavored to analyze their efficacy.

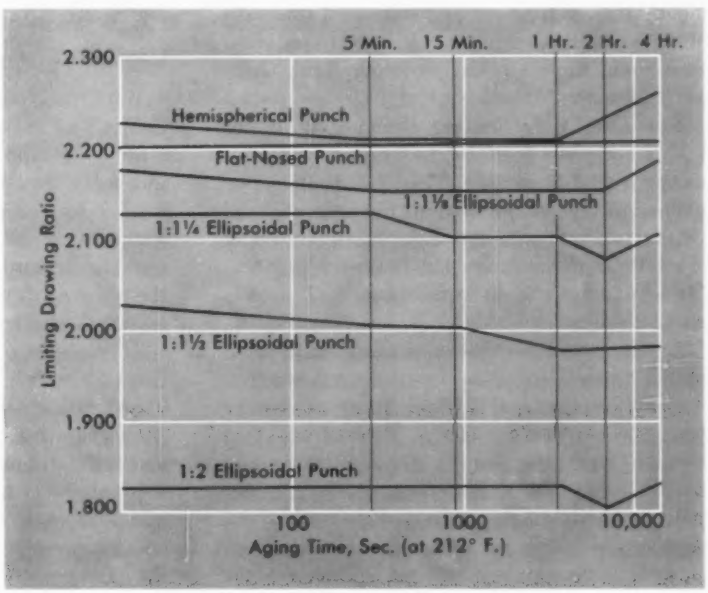


Fig. 1 – Curves Reveal That Limiting Drawing Ratios as Determined by Swift Test Do Not Follow Clearly the Detrimental Effect of Increased Aging on Skin-Passed Sheet Steel. Best correlation – still not pronounced enough for practical use – came when tests were made with an ellipsoidal punch having a minor-to-major axis of 1:1½

There was no general agreement as to whether cup forming tests are adequate for certain larger pressings. It was, however, thought logical to consider the test as a specific one in a press shop that used the testing machine itself for production purposes, or which operated the testing machine under conditions as near as possible to those existing in production. If metal is drawn at ratios which are different from those actually used in the press shop, the test information may be completely wrong.

It results that, while the cup-forming test is a very useful one, a measure of caution on drawing ratios is necessary. As with other methods of testing, the limits of validity of a

test result should generally be determined, rather than merely cite its limitations. Is it better to examine the experience so far gathered by existing technological testing methods, or to propose new ones? The general tone of the meeting seemed to suggest the former would be the better plan.

The Swift Test

The research department of the Metals Division of Imperial Chemical Industries in Birmingham, England, investigated the Swift cupping test, now some 30 years old, to determine the reproducibility and correlation of its results on three independent presses and four types of metal, namely rimming and stabilized steel, 70-30 brass, and aluminum. It was found that aluminum imposed the strictest limitations; an increment in blank size of 1.25 mm. (when determining the "limiting drawing ratio" or L.D.R.) appeared to be too highly discriminating for this metal. This L.D.R. may be defined as the maximum blank diameter divided by the punch diameter, and the maximum blank diameter is defined as "that diameter of blank for which there is an equal chance of success and failure".

Nature and smoothness of surfaces of both punch and die have an important influence on cupping results, and various types of surface were used to "test the test". It was found that surface roughness of brass and aluminum blanks made little difference to the L.D.R., though with a rough punch and smooth die the drawing performance of smooth aluminum sheet was two increments better than for the rougher sheet.

With all combinations of tooling, "rough" steel drew better than smooth. (Measured on a "Talysurf" instrument in micro-inches, centerline average, the "rough" steel was 60 to 70 and the smooth steel 35 to 45.) It was found both from correlation tests and surface roughness tests that the increment in limiting drawing ratio for aluminum should be doubled (from 0.025 to 0.050) to give comparable results with brass and steel.

The elaborate precautions in this and other investigations to correlate results could never be taken in a standard shop floor test. This must be cheap and rapid. Nevertheless, the conclusion was reached that only by extremely careful and possibly tedious investigation could a simple and reliable shop floor test (which is certainly needed) be developed and the governing variables of the cupping operation be specified.

Work by Ullmann and others at Richard Thomas & Baldwins Limited on the Swift test, using a variety of punch shapes, showed that it did not provide a close correlation between the expected formability of a steel and the length of time it had been aged (Fig. 1). This is unfortunate, since a major cause of split and imperfect stampings is the use of rimming steel which has aged. ("Aging" is first observed as a kink at the yield point on the stress-strain curve, and next by a rise in the yield point, which can be of the order of 9000 psi. for fully aged material.)

Conclusion

While it is difficult to summarize the conclusions of an extensive conference in a few sentences, some remarks may be quoted made by Prof. O. Svahn of the Institutionen für Mekamiok Teknologi, Göteborg, Sweden, one of the initiators of a small international group to standardize cupping tests in 1954 from which the present International Deep Drawing Research Group emerged:

"The object of the work in progress is to improve knowledge about different materials suitable for deep drawing and about methods to force them into a certain form in the simplest, most effective and cheapest way. Many testing methods are available – some simple, some complex – yet no single one is universally satisfactory. Simple ones are preferable but they do not always correspond to the facts of life. The theoretical side is now fairly clear; we can analyze the demands made on the metal during deformation. But metallurgical conditions and physical demands on the metal require further basic research to find why the metal reacts in a given way. Such a reaction should be studied from two viewpoints – (*a*) material behavior due to its inherent properties, and (*b*) behavior due to external forces, tool shape, roughness, lubrication, speed and temperature.

"Future requirements are better materials for deep drawing, better methods for industrial practice, and evolution of simple tests which can be standardized internationally. This conference forcibly illustrates the fact that there is still a long way to go to achieve these objectives."

Progress With 25% Nickel Steels for High-Strength Applications

Nickel steels containing 18 to 27% Ni have high strength and excellent cold working characteristics. Properties result from a combination of precipitation and transformation hardening. (A-general, Q-general; Fe-b, *Ni*, SGB-a)

WORK HAS BEEN UNDER WAY for some time at the Bayonne Research Laboratory of the International Nickel Co., Inc., on the evaluation of experimental low-carbon (less than 0.05%) nickel steels for high-strength applications. The new series is responsive to combined precipitation and transformation hardening when annealed, air cooled and aged. Nickel content may be varied from about 18 to 27%. Response to precipitation hardening derives from controlled additions of titanium and aluminum.

In this progress report, all information is based on laboratory heats. Alloy compositions, treatments and properties discussed are the results of a continuing program of evaluation.

20% Nickel Gives High Strength

A 20% nickel steel of the type under development will undergo transformation from austenite on air cooling from a solution annealing temperature of about 1500° F. and will have an annealed hardness of about Rockwell C-35. Aging at 850 to 1000° F. results in precipitation hardening. Composition, heat treatment and resultant properties are as follows:

Composition: 30 Ni, 1.7 Ti, 0.2 Al, 0.4 Cb.

Heat Treatment: Anneal 1 hr. at 1500° F., air cool; age 1 hr. at 950° F. air cool

Data cited in this article were furnished by C. G. Bieber, head, special alloys section, Research Laboratories, Development and Research Div., International Nickel Co., Bayonne, N.J.

Tensile properties (standard 0.252-in. diameter specimen):

Yield strength (0.2% offset)	270,000 psi.
Tensile strength	279,000 psi.
Elongation	12%
Reduction in area	57%
Notched tensile strength	323,000 psi.

Data on notched tensile strength were obtained on specimens with a parallel section diameter of 0.300 in. and a 60° circumferential notch at midlength. Root radius of the notch was 0.0006 in., depth about 0.045 in.

The 20% nickel steels may be cold worked and they are characterized by a particularly low work hardening rate. One steel with an annealed hardness of Rockwell C-36 had essentially the same hardness (Rockwell C-37) after being cold worked 70%. Stress-strain curves also reflect this low work hardening behavior.

Two Aging Treatments Needed

A steel containing 25% Ni has a somewhat lower M_s temperature than does one with 20% Ni; consequently it can be solution annealed to a lower hardness (Rockwell C-5 to 15). After annealing and prior to final aging, the 25% Ni steels must be heated to about 1300° F. for 4 hr. and air cooled to provide the desired hardening and transformation. At this temperature, the titanium and nickel held in solid solution are precipitated as a complex. The depletion of these two elements from the austenite matrix raises the M_s temperature of the steel so that it

Table I – Notched and Smooth Bar Tensile Properties of 25% Nickel Steels

Treatment	Smooth Bar				Notched Bar Tensile*	Notched to Smooth Tensile Ratio
	Yield	Tensile	Elongation	Reduction in Area		
Composition: 24.3% Ni, 1.6% Ti						
1500° F., 1 hr.†; −100° F., 16 hr.; 850° F., 4 hr.	234,000 psi.	253,000 psi.	14%	58%	—	—
1500° F., 1 hr.; cold reduced 50%; −100° F., 16 hr.; 850° F., 1 hr.	267,000	275,000	12	61	402,000 psi.	1.46
Composition: 27.6% Ni, 1.5% Ti, 0.15% Al, 0.43% Cb						
1500° F., 1 hr.‡; 1250° F., 4 hr.; −100° F., 16 hr.; 850° F., 1 hr.	249,000	281,000	13	61	273,000	0.97
1500° F., 1 hr.; cold reduced 50%; 850° F., 1 hr.	254,000	280,000	13	61	364,000	1.30

*All notched tensile data were obtained on specimens with a parallel section diameter of 0.300 in. and a 60° circumferential notch at midlength. Root radius of the notch was 0.0006 in., depth about 0.045 in. This gave a stress concentration factor, K, of 10.

†Annealed hardness: Rockwell C-25. ‡Annealed hardness: Rockwell C-15.

undergoes at least partial transformation when cooled to room temperature. Refrigeration at about −100° F. may be applied, if necessary, to promote further transformation.

This treatment is followed by a final age of 1 hr. at 850 to 950° F. Composition, treatment and representative properties achieved for a given steel of this type are cited below:

Composition: 24.8 Ni, 1.6 Ti, 0.18 Al, 0.4 Cb

Heat treatment: Anneal 1 hr. at 1500° F., air cool; intermediate age 4 hr. at 1300° F., air cool; age 1 hr. at 950° F., air cool.

Tensile properties (standard 0.252-in. diameter specimen):

Yield strength (0.2% offset)	252,000 psi.
Tensile strength	277,000 psi.
Elongation	12%
Reduction in area	44%
Notched tensile strength	298,000 psi.

In the annealed condition, the same steel exhibited these properties:

Treatment	Strength	
	0.2% Yield	Tensile
1 hr. at 1500° F., air cool	67,500 psi.	120,600 psi.
1 hr. at 1600° F., air cool	34,700	114,900

Elongation was 45%; reduction in area, 68%.

Good Cold Working Properties

Nickel steels containing 25% Ni are easily cold worked. These steels have very good tensile strength ratios, notched to smooth bar, when they have been cold reduced prior to final aging. Typical data are shown in Table I.

Section size appears to have little effect on properties developed after full heat treatment. Final properties are about the same whether the steel is furnace cooled or quenched in brine from the annealing temperature. The insensitivity of final tensile properties to such a spread in cooling rate from the annealing temperature indicates that the steel should respond satisfactorily to heat treatment over a wide range of section sizes.

Welding Studies in Progress

Filler metals and welding techniques are currently being evaluated. Fully heat treated steels are capable of withstanding the thermal shock associated with a welding arc. No preheat is necessary. A narrow region in the heat-affected zone of the parent metal experiences fairly complete solution-anneal softening during welding and post-weld treatment is required to restore this zone to its original strength level.

High-Hardness Alloys

Of more than passing interest are some preliminary hardness tests made on steels of about 25% Ni with a combined aluminum and titanium content of 6 to 8%. When such alloys are given a special heat treatment, they develop a hardness of Rockwell C-66 to 67. As with the alloys of lower titanium and aluminum content, these steels are readily hot workable in the solution annealed condition. Initial working, at least of heavy sections, should preferably be performed on material stripped hot from the mold and thermally equalized at the desired working temperatures.

How Electric Home Heat Finally Became a Reality

The extraordinary versatility of Nickel that today brings you electric home heat could tomorrow bring a solution to a metal problem in your own business

Ever have a metal problem you couldn't find the answer to . . . and then discover that the solution was there all the time?

The people in the electric home heating industry needed a resistance wire that had special properties: strength and durability for long-term service – resistance to oxidation and extreme heat – good electrical resistance properties for efficient and economical operation.

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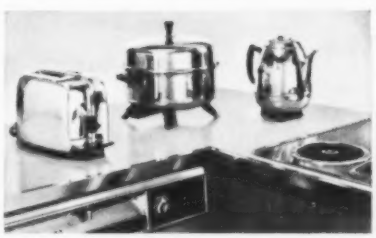

Dependable appliances use Nickel. Electric ranges, dishwashers, toasters, percolators, irons . . . all rely on Nickel alloy resistance wire heating elements for long service life.

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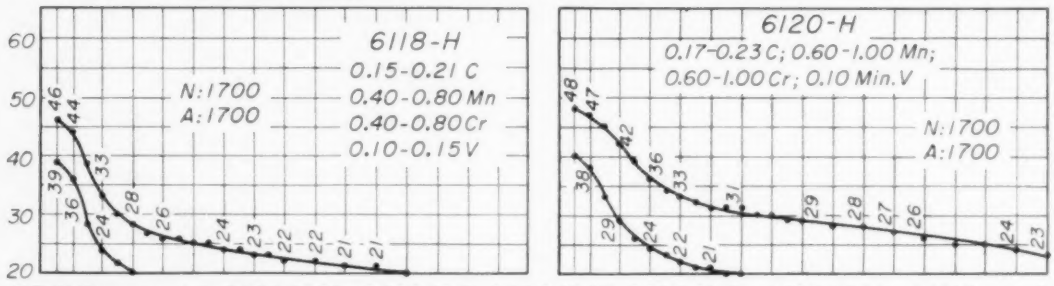
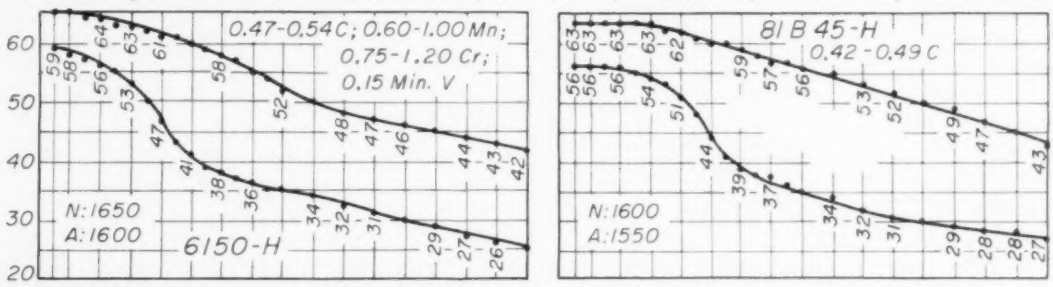
Hardenability Bands for Steels 6118-H to 8630-H

A.I.S.I., February 1960

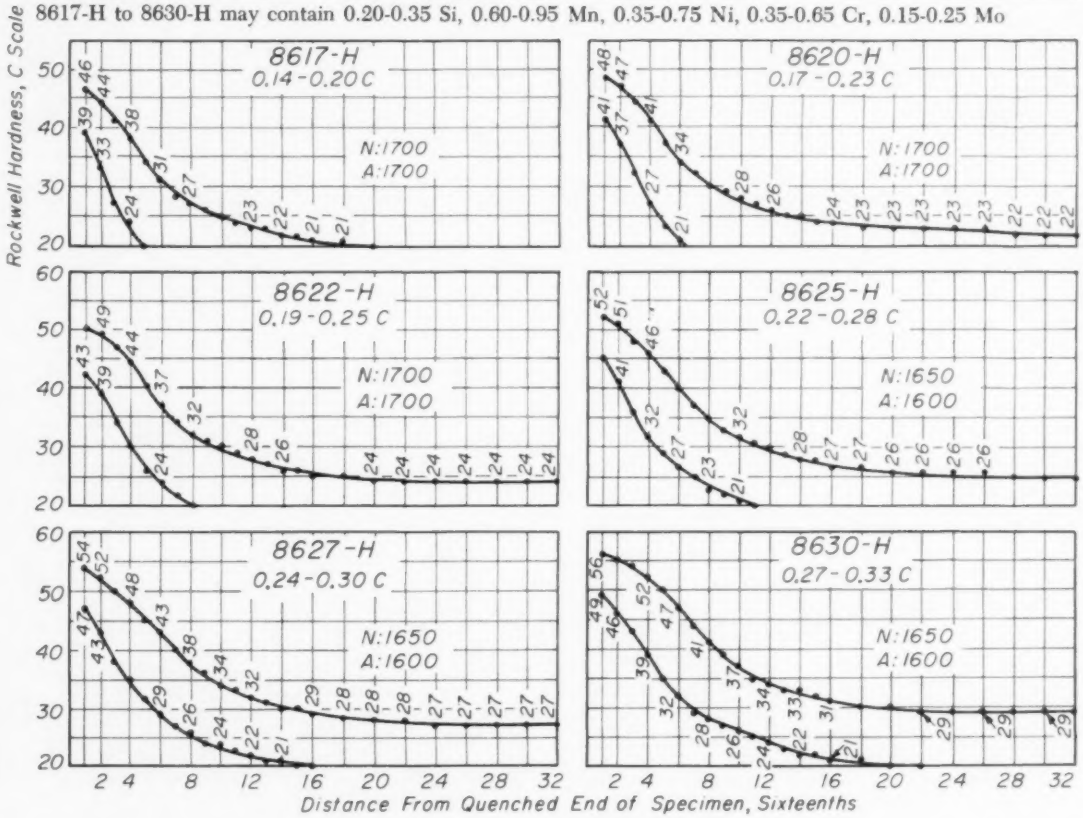
61xx-H Series may contain 0.20-0.35 Si; C, Mn, Cr and V as shown



81B45-H may contain 0.75-1.05 Mn, 0.20-0.35 Si, 0.15-0.45 Ni, 0.30-0.60 Cr, 0.08-0.15 Mo, 0.0005 min. B.



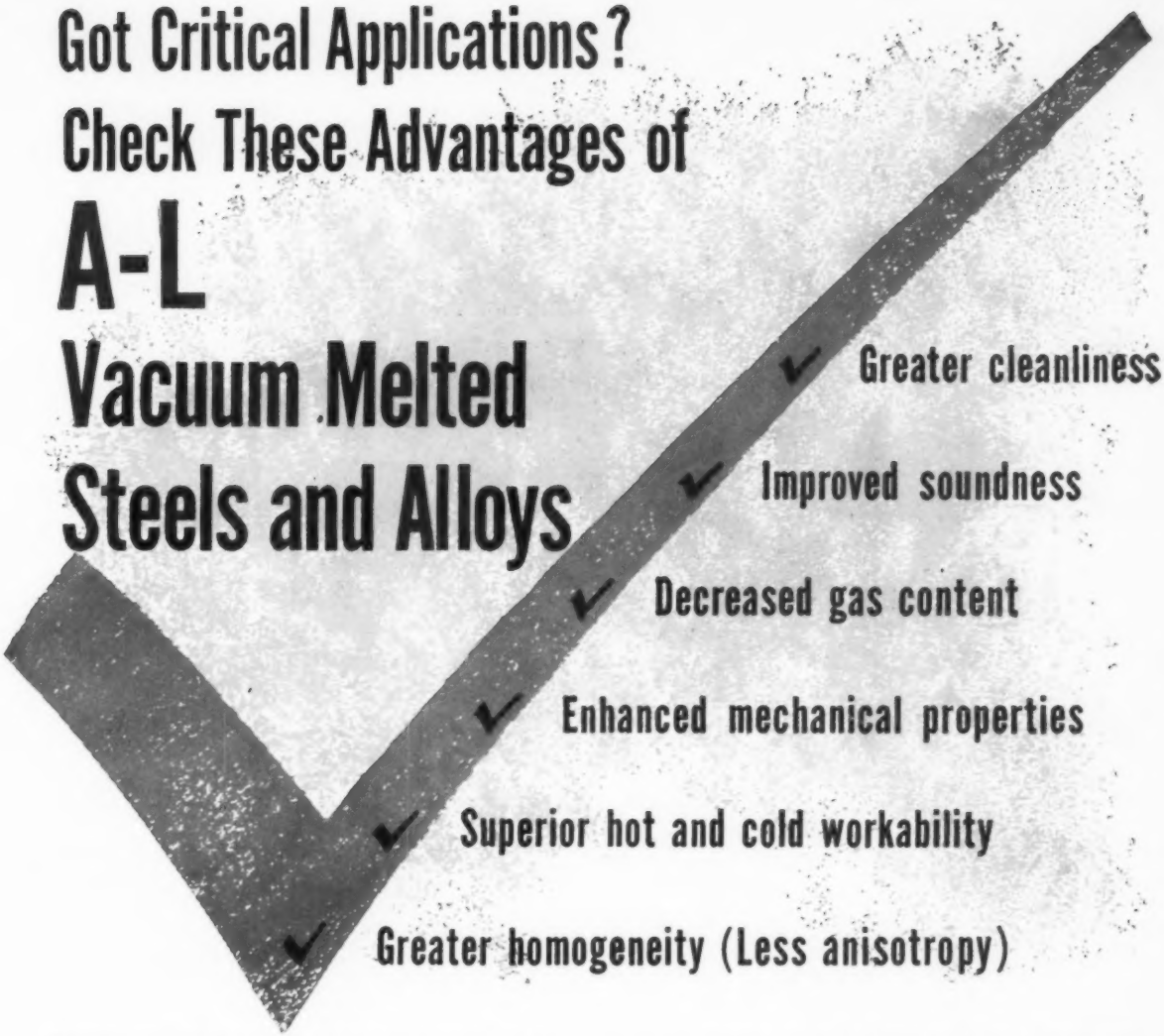
8617-H to 8630-H may contain 0.20-0.35 Si, 0.60-0.95 Mn, 0.35-0.75 Ni, 0.35-0.65 Cr, 0.15-0.25 Mo



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.)

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

Got Critical Applications? Check These Advantages of A-L Vacuum Melted Steels and Alloys



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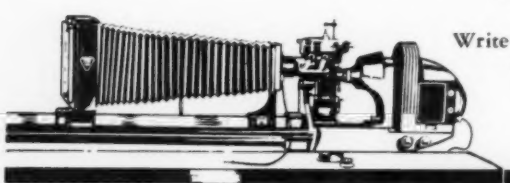

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Quenching in the Automatic Production Line

*By O. E. CULLEN**

This article discusses the factors involved in designing the quenching section of a heat treating line for automatic operation. To realize true economies, the engineer must balance the costs of new equipment against the savings which can result from less labor and lower rejection rate. (J26, 18-74)

RAPID STRIDES in automatic operation in the various fields of metal processing have inspired engineers to apply similar methods to heat treating lines. Since the quenching operation is an integral part of the heat treating process, we must also consider the possibilities and practical aspects of introducing automation into quenching.

Some of the Problems

However, before deciding on automatic operation, questions concerning its real advantages should be answered:

- Can we make full use of such innovations in our particular process?
- Will automatic quenching be helpful because it eliminates handling, or improves the quality of the product, or both?
- Can it aid in the over-all economics or quality of the work which is being handled in a continuous production line?

The advantages we hope to gain from automatic quenching must also be considered in relationship to the entire heat treating process. Though savings may be possible by cutting down handling costs, they must be balanced against the added costs of additional heat treating equipment, maintenance, equipment supervision, and safety precautions.

Many are the problems involved in converting to automatic operation. We must consider the handling of the work ahead of the quenching step, and also how we are to move material through the heat treating furnace. This may include a study of the practicability of using trays, fixtures, plugs and the like. We may have to determine how the work is to be brought to the heat treating furnace so that it can be loaded economically in the necessary manner. We must study the added equipment, both automatic and manual, from the standpoint of its intricacy and the possible maintenance problems which may be involved in its upkeep. After all, fully automatic lines may be beautiful to look at, but they are only serviceable when they are operating.

The supervision required for automatic equipment must be considered, not necessarily from the standpoint of the labor no longer needed (as compared to the labor needed for manual handling), but from the standpoint of the technical knowledge required. Naturally, the cost for good supervision must be compared with that for proper manual operation. More safety precautions may be needed. We must take into account the cost of these added features as part of the price we pay for the

*Chief Metallurgist and Manager, Research and Development Dept., Surface Combustion Div., Midland-Ross Corp., Toledo, Ohio.

Automatic Line in Action. At this point in the gas carburizing line, a steady stream of trayloads of a wide variety of carburized truck transmission parts emerges from the quench tank at the right and enters the washer at the upper left. Due to suitable tray loading and quench station design, there is no need for manually handling any of these parts for plug or fixture quenching

development of a fully automatic quenching arrangement.

Some of the Advantages

However, there are advantages. For one thing, automatic quenching procedures are possible to some degree regardless of the type of product being heat treated. Generally, such systems are adapted to quench parts which can either be dropped through the quenchant onto a conveyer belt (see Fig. 1, p. 103), or carried on trays or baskets for further processing through the heat treating and production lines. Symmetrical parts, such as bearing races, shafts, ring gears and the like, can also be readily adapted to continuous mechanical movement through a heat treating furnace, to quenching presses and out of these presses under fully automatic conditions.

However, as the demand for automatic quenching increases with the increase in continuous heat treat processing lines, we may be faced with the necessity for handling, automatically, some unusual forms of work. Reviewing our progress during the past several years, we can take heart in the knowledge that many unusual quenching problems which would normally require manual handling have been successfully adapted to automatic handling by applying new and improved metallurgical knowledge to the process. For example, plug quenching has been eliminated in many parts by proper selection of quench tank arrangement, quenching medium, and quenching temperature.

Quench Tank Design

Let us now consider some features which might be needed in automatic quenching setups. As an example, a quench tank should incorporate typical design features which aid automatic operation. In conjunction with suitable spacing and fixturing on the trays which carry the work through the furnace, the quench tank should have suitable agitation (and guiding for this agitation) to provide uniform quenching. It should attain and hold the desired temperature in the quenching medium.

As an example, Fig. 2 illustrates a suitable tank. Such a tank, oftentimes in conjunction with changes of varying degree in the design of a part, the method of prefabricating, or in the selection of the alloy, has proven very successful. In many instances, the complete design of the heat treating line, including carburizing equipment, washing equipment, hardening furnaces, tempering furnaces, and methods of handling between each of these stations, has been engineered to meet the needs for special quenching techniques so that a fully automatic production line could be used.

In summarizing, we can say that noteworthy progress has been made and will continue to be made. However, it should be borne in mind

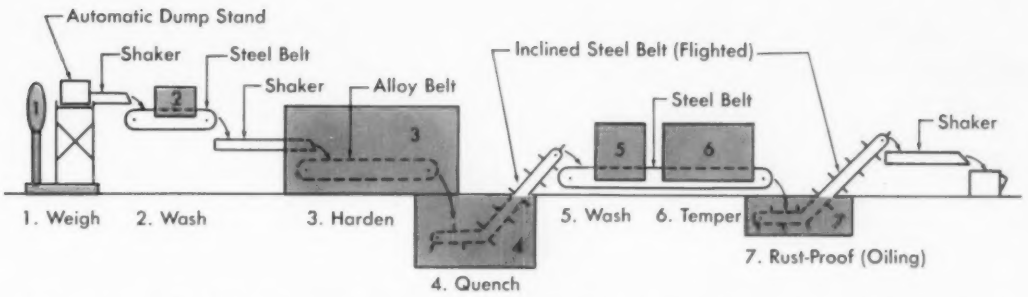


Fig. 1 – Typical Line for Hardening and Tempering. This and similar lines for carburizing, carbo-nitriding, homogeneous carburizing or carbon restoration can be easily adapted to fully automatic production

that the most important advantage of automatic quenching is the elimination of variables in the process. We should thus evaluate its benefits primarily from this standpoint. Cost reduction at this point, if any, should primarily result from cutting down on rejects, and from the ability to produce consistently a product which can be handled more economically after the quenching process.

As might be expected, automatic quenching is particularly adapted to large quantities of similar parts, or, at least, to parts having similar requirements for quenching. Actually, there are no limits to the size or intricacy of shape, or even to the extent of fixturing – providing, of course, that the other conditions affecting automatic quenching are under control. We believe that today's knowledge of mechanical handling equipment design, handling of quenching mediums, and control of metallurgical properties of the work favor successful automation in almost any situation in which it is applied. Furthermore, there is no reason to doubt that a correct correlation of material selection, machining technique, heating equipment, and any other auxiliary operations in the production line can be complemented by an automatic quenching installation.

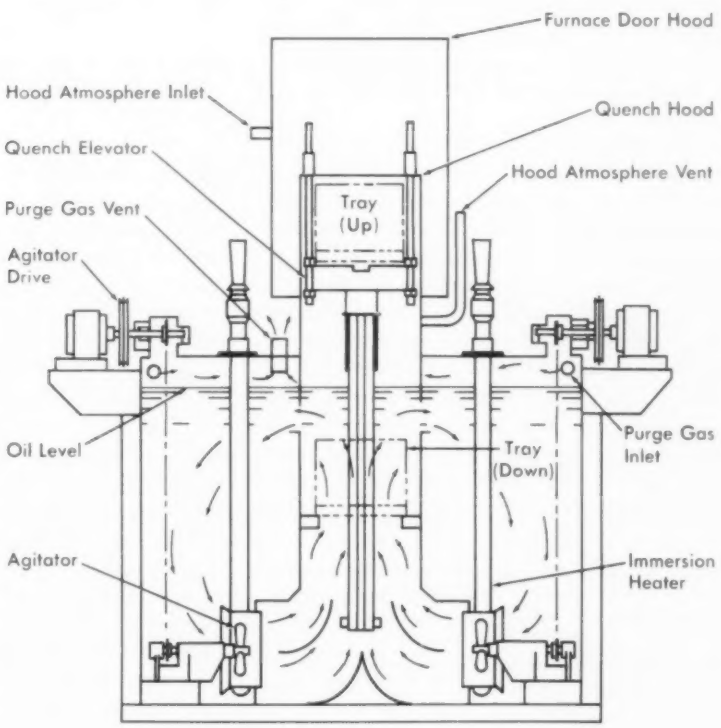


Fig. 2 – A Well-Designed Quench Station Can Eliminate the Need for Plug or Fixture Quenching Many Parts After Heating for Carburizing or Hardening. Directional vanes in the oil stream distribute the oil flow uniformly. The unit is designed to handle hot oil up to about 400° F. by including combined heating and cooling elements as well as provision for blanketing the surface of the hot oil with an inert gas atmosphere

Modified 4340, Heat Treated to 270,000 to 300,000 Ultimate

*By J. C. CHANG, F. J. HERR and J. W. SWEET**

Steels made by three methods – basic electric, vacuum induction, and consumable arc – were studied and their longitudinal and transverse properties evaluated as well as their toughness and fatigue resistance both statically and dynamically. (Q-general, 3-70; AY)

LOW-ALLOY STEEL HAS BEEN USED for various aircraft components, and S.A.E. 4340 (nominally 0.40% C, 1.8% Ni, 0.8% Cr, 0.25% Mo, aluminum killed) is a good example. Forgings heat treated to about Rockwell C-40 hardness, corresponding to ultimate tensile strength of about 180,000 psi., have seen much service as attachment fittings for fuselages and wings, for bulkheads and for engine mounts. Heat treated to a lower hardness (C-32 or 150,000 psi.), it makes good jet engine turbine shafts and compressor disks. Heat treated to a higher hardness (C-50 or 260,000 psi.), it has been put into landing gear, and more recently into structural items for missiles.

About seven years ago the International Nickel Co.† published the properties of a modification of 4340 containing somewhat higher content in all alloying elements and with silicon raised from the standard 0.25% to 1.5%. Its nominal composition is 0.40% C, 0.75% Mn, 1.5% Si, 2% Ni, 1% Cr, 0.4% Mo. Basic electric steel of this alloy (termed 300 M) was studied by the Aero-Space Division of Boeing Airplane Co. during 1958 and we became convinced that it would be a very good alloy for parts requiring 270,000 to 300,000 psi. tensile strength. While this would be most acceptable in forgings for aircraft landing gear, it would be even more desirable for motor cases and fuel tanks for missiles. The latter, made of sheet perhaps 0.070 in. thick, had been especially erratic under proof test and even in performance.

*Messrs. Chang and Herr are research engineers, and Mr. Sweet is chief metallurgist for the Aero-Space Division of Boeing Airplane Co., Seattle, Wash.

†See "Symposium on Ultra-High-Strength Steels in Aircraft Applications", published by Society of Automotive Engineers, New York.

Since this alloy steel is now being made by three processes, it was decided to evaluate the effect of steelmaking practice on the properties of forged bars. Data from this investigation will be presented in this article. Next month we will give the results of our studies of sheet and thin plate.

Gas Analysis Versus Melting Method

Gas	Basic Electric Air Melted Under Slag	Vacuum Melted and Cast	
		Induction	Consumable Electrode
Hydrogen	1 to 20 ppm.	< 1 ppm.	< 2 ppm.
Oxygen	50 to 125	5 to 15	5 to 25
Nitrogen	30 to 500	5 to 50	10 to 100

Steelmaking Processes

The basic electric steelmaking process has been so long established as the method *par excellence* of making quality steels that most of the younger generation of American metallurgists have never come in contact with crucible steel or acid openhearth. However, they have learned that a very minor content of gas has a surprisingly detrimental influence on "quality" – hence the space given recently in technical publications to various ways for vacuum casting of air-melted heats. Also they have read about the commercial production of steels both melted and cast in vacuum in an effort to reduce gas content to an absolute minimum. In fact there are two such processes; in one the raw materials are melted in a crucible by induced electric currents (induction vacuum melting) and in the other husky bars of the proper steel are used more or less as electrodes and an ingot mold filled drop by drop in this "consumable electrode vacuum melting".

W. W. Dyrkacz of Allegheny Ludlum Steel Corp. has summarized the case for vacuum melting in *Metal Progress* for May 1959, p. 138, by quoting representative gas analyses of low-alloy engineering steels as shown at the top of the next column. On the premise that high gas content means many inclusions, Mr. Dyrkacz said that vacuum-melted steel should (*a*) be cleaner, (*b*) work better, hot or cold, (*c*) have better mechanical properties and (*d*) be sounder. He said that consumable electrode steel should (*a*) be cleanest because it avoids any contamination from the necessary crucible in the induction furnace, (*b*) be free of ingotism and segregation since the metal freezes rapidly, drop by drop, (*c*) be sounder especially in big billets and have higher fatigue strength at room temperature, especially in transverse directions, and finally (*d*) be less costly than induction melted ingots of large size.

We aimed to verify some of these important claims by testing forged billets and bars of 300 M steel obtained from commercial suppliers and made by the three processes cited above.

Materials Under Test

Four bars of air-melted steel were taken from metal for landing gear assemblies and supplied by Republic Steel Corp., International Nickel Co. and Crucible Steel Co. of America. They were of three sizes: 12-in. squares, 4-in. squares and 4 × 5-in. rectangles.

Six bars of induction vacuum-melted steel ranging from 2½ × 12 in. to 6 × 7 in. were secured from two heats by Crucible Steel Co.

Eight bars of sizes ranging from 10 in. square to 2 × 4 in. were forged from a single 16-in. round ingot made by consumable arc melting of air-melted electrodes.

While gases were not determined, the chem-

Table I – Chemical Composition (Range) of 300 M

Element	Basic Electric	Induction	Consumable Electrode
Carbon	0.36 to 0.395	0.41 /0.42	0.376
Manganese	0.68 to 0.79	0.82 /0.76	0.46
Phosphorus	0.007 to 0.016	0.004/0.003	0.010
Sulphur	0.008 to 0.014	0.007/0.006	0.017
Silicon	1.44 to 1.72	1.57 /1.60	1.64
Nickel	1.75 to 1.85	1.93 /1.88	2.05
Chromium	0.82 to 0.83	0.84 /0.84	0.98
Molybdenum	0.38 to 0.45	0.41 /0.43	0.36
Vanadium	0.07 to 0.09	0.07 /0.07	0.06
Aluminum	— to 0.08	0.077/0.064	0.095

Table II – Representative Longitudinal Tensile Properties

	Ultimate	Yield	Elongation	R.A.
Basic electric steel; average of four samples from 4 × 5-in. bar				
Mid-radius	291,900	244,500	9	36.9
Center	287,300	243,400	10	37.7
Induction melted; average of samples cut from 4-in. square bar				
Center	285,600	240,000	11	46
Midway	282,900	242,300	11	47.5
Edge	283,700	243,100	11	48.5
Consumable electrode; 7 bars ranging from 6 × 11 in. to 2 × 4 in. Samples cut midway between center and edge				
Highest	291,400	250,000	13.0	50.3
Lowest	280,700	238,600	11.0	42.2
Over-all average	285,900	244,800	11.9	47.2

Air-Melted *Induction-Melted* *Consumable Electrode*

Fig. 1 — Oxide and Sulphide Inclusions Midway Between Edge and Center of 4 × 8-In. Bars. Unetched; 75 ×

ical compositions shown in Table I show no aberrations, except perhaps that silicon is unduly low in one basic electric bar. The low sulphur and phosphorus content is notable and leads one to think that inclusions would be vanishingly few — an error as can be seen from Fig. 1; *all* varieties have a good many. It can be concluded that consumable arc melting *in vacuo* does not of itself eliminate dirt particles. This evidence also indicates that quite clean steel can be made by vacuum induction melting.

One of the four air-melted bars (4 × 4 in.) had low ductility in transverse direction, 4% average elongation and 10% reduction of area, compared with similar tests on the other three bars: 7% average elongation and 31% reduction of area. Microscopic examination revealed that it contained long stringer inclusions, and the other three had scattered inclusions as shown in Fig. 1.

Tension tests in the longitudinal direction were uniformly good and showed small variation whether located at center of bar, edge or midway. No influence of steelmaking practice could be discovered. The Jominy hardenability curve for this analysis is almost a horizontal line, so the variation in longitudinal tensile properties, bar to bar, is due to testing variables, slight variations in tempering response, and minor differences in chemical analysis. (All microstructures appeared to be 100% tempered

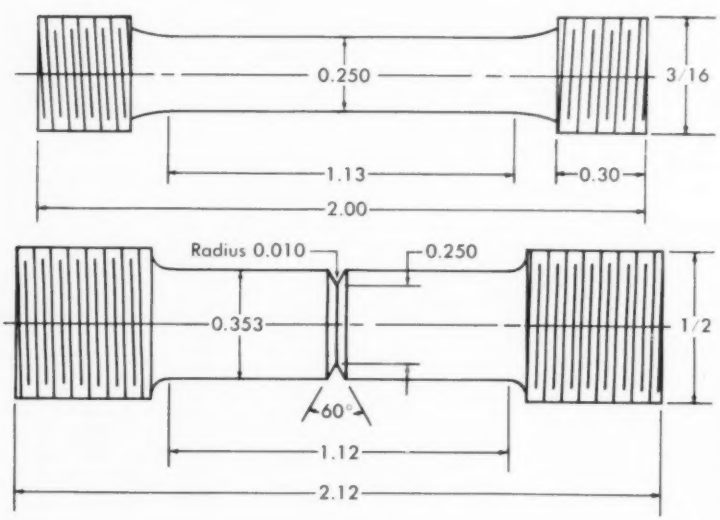


Fig. 2 — Sub-Size Tensile and Notched Tensile Specimens for Transverse Tests. Notch depth and radius gives stress concentration of 3.3 at root of notch

martensite, although X-ray analysis showed about 2% of retained austenite in very stable condition.) Representative values for the three classes are shown in Table II. Even the lowest figures noted gave excellent properties, but the air-melted bars have somewhat lower figures for elongation and reduction of area and the consumable electrode bars possessed the best longitudinal ductility.

Notched-Bar Strength

While "toughness" has traditionally been measured by the impact strength of a notched Izod or Charpy specimen, the tendency now is to appraise this rather poorly defined but important property by comparing the tensile properties of notched versus smooth tensile specimens taken in a direction transverse to that of principal extension in forging or rolling. Inclusions or other heterogeneities in the original ingot may be expected to play an important part in such a comparison, since they produce an increasingly damaging banded structure with increasing reductions from the original ingot dimension. Theory indicates that the "notch-strength ratio" of a steel – that is, the ultimate tensile strength of a notched specimen divided by the ultimate tensile strength of a smooth specimen – should be greater than unity if the steel is to be able to prevent rapid brittle failure from starting at some small existing crack or inclusion*. Consequently we gave much attention to this matter in our study of the 300 M steels.

Since some of the forged bars we wished to study were 2 to 3 in. measured in the short transverse direction, some of our test specimens were correspondingly sub-size, as shown in Fig. 2. They were threaded at ends for correct and secure alignment in the testing machine's grips. The unnotched specimens were held to 0.003 in. tolerance along the gage length; the V-notch 0.052 in. deep with bottom radius of 0.010 in. gave a stress concentration K_t of 3.3.

When the individual short transverse tests from rectangular bars of all three varieties of steel are plotted, reduction of area against ultimate tensile strength, the points all fall within a band between 270,000 and 300,000 psi. The lowest reduction of area of *unnotched* transverse bars from air-melted bars is 6%, the highest 30%, and there seems to be a trend for the more ductile to be the stronger. Transverse test pieces from vacuum-melted bars had reduction of area scattered from 3% to 37.2%; however, 38 out of 55 had ductility of 18% or greater. Range of transverse ductility of the smooth-bar tests from consumable electrode bars was 2% lowest to 26.6% highest. Fifty out of 54 results were about evenly scattered between 6 and 23% reduction of area.

When reduction of area is plotted against notch-strength ratio (ultimate strength of notched tensile specimens divided by ultimate strength of smooth specimens) the samples from air-melted stock show a scatter between ratio of 1.0 and 1.31. Consumable electrode stock also seems to scatter between 0.84 and 1.29. However, Fig. 3 shows what appears to be a definite trend for the stock induction melted in vacuum, wherein the notch-strength ratio appears to go up as transverse ductility (reduction of area) increases.

It would appear from these results, summarized in Table III, that transverse ductility and notch-strength ratio are low for bars of large square cross section and for thin rectangular slabs (3 in. or less) forged from the consumable electrode ingot. The poor results from the 10-in. bar are thought to be due to deficient forging reduction from the 16-in. ingot; a macro-etched section shows a pronounced dendritic pattern. Likewise there is some danger of too much forging reduction in one direction; the short transverse ductility of the 3-in. slabs is also deficient.

Disregarding the one air-melted bar which had excessive inclusions, it would appear that the transverse properties of the other three are comparable to those of the consumable electrode bars 4 to 5 in. in minimum dimension. While the air-melted bar has nowhere near the excellent transverse ductility (reduction of area) of the induction-melted bars, 4 in. square, the former has a much lower price. Likewise the lower ductility of some tests plotted on Fig. 3

*EDITOR'S FOOTNOTE – See a series of articles in the August issue of *Metal Progress* on the problem of brittle fracture. Landing gears need good basic properties such as ultimate strength, yield strength, ductility and notch-tensile strength, but also (perhaps to a greater degree) other things such as resistance to crack propagation, to hydrogen embrittlement, and to stress-corrosion cracking. Since all these depend on chemical analysis, heat treatment, residual stress, rate of application or duration of applied stress, and section thickness, and since no ideal material has yet been discovered which is best at all working temperatures, the designer cannot be blamed for figuring on minimum ranges of test data rather than the most that can be got from a given steel.

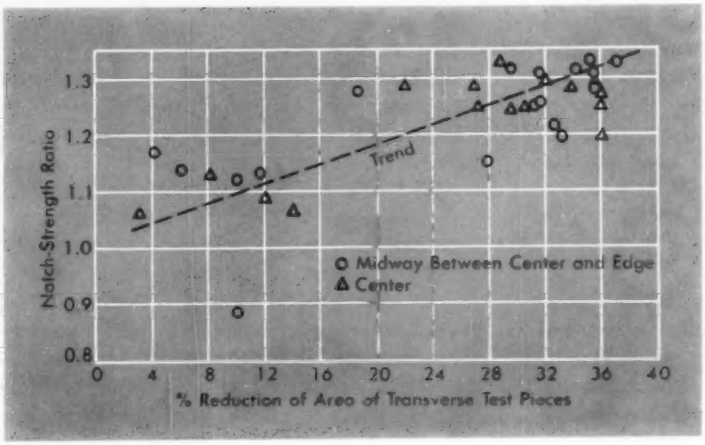


Fig. 3 – Seeming Trend Upward of Transverse Notch-Strength Ratio (Ultimate Strength of Notched Versus Smooth Bars) as the Reduction of Area Increases in Induction Vacuum-Melted Steel

are either from a 6 × 7-in. bar where the ingot structure may not have been broken up, or from a 2.5 × 12-in. bar which has been too severely worked.

Embrittlement

Since many aircraft parts are electroplated for corrosion resistance, and even the best plating techniques may put some hydrogen into solution in the steel, the susceptibility of these three 300 M steels to hydrogen embrittlement was investigated. The test pieces were cut longitudinally, and were similar in design to the notched bar shown in Fig. 2; dimensions were 3 in. between shoulders, 0.333 in. diameter, notched in center 0.050 in. deep. All were Magnafluxed. Bottom of notch was finished by rapid rotation under 0.010-in. wire in slurry of oil and fine abrasive to remove all tool marks.

Four plating methods were used:

1. High-efficiency cadmium electrolyte with brightener at 20 amp. per sq.ft. followed by a

Table III – Notched-Strength Ratio of Tranverse Bars K_t-3.3
(Figures are averages of three or four tests)

	Average Ultimate Strengths		R.A., Smooth	Ratio B÷A*	Charpy Impact
	Smooth (A)	Notched (B)			
Air-melted bars					
12-in. square, midway	274,900	341,900	16.3%	1.23	—
center	273,600	346,900	18.8	1.25	—
4 × 5-in. bar, midway†	289,300	313,100	24.2	1.07	—
center	286,100	346,900	19.2	1.26	—
Induction melted bar					
4-in. square, midway	288,200	383.5	35.5	1.33	—
center	284,300	362.3	35.1	1.26	18.3
Consumable electrode bars					
10-in square, midway	296,500	307,300	8.8	1.07	8.6
center	286,100	312,600	4.8	1.09	7.3
5 × 10-in. bar, midway†	280,800	308,900	15.3	1.09	9.8
center	280,000	315,800	13.3	1.11	11.3
4-in. square, midway	283,500	332,800	21.7	1.17	10.7
center	284,800	327,200	13.2	1.14	9.9
3-in. slab, midway†	279,300	292,100	9.6	1.03	9.8
center	280,500	301,100	11.7	1.07	7.6

*A is the *maximum* ultimate strength of any test piece in the group.
† Short transverse test.

23-hr. bake at 375° F. Plate was 0.0005 in. thick.

2. Standard cadmium electrolyte with brightener at 20 to 40 amp. per sq.ft. followed by 23-hr. bake at 375° F. Plate was 0.0005 in. thick.

3. Chromium plate, current density 300 to 700 amp. per sq.ft., followed by 3-hr. bake at 600° F. Plate was 0.002 in. thick.

4. Acid electroless nickel plate (glycolate), 0.001 in. thick, followed by 3-hr. bake at 600° F.

Details of these solutions are given in the footnote.*

Professor Troiano in his recent Campbell Memorial Lecture, summarized in February's *Metal Progress*, p. 112, points out that hydrogen in steel induces "static fatigue" – that is, if a notched tensile bar of hydrogenated steel is loaded slightly less than its normal ultimate strength, it will hold the load for a certain time but then break. The so-called incubation time for fracture is longer as baking time increases (as the hydrogen in solution decreases).

Our procedure therefore was to load the specimen, which had been notched for $K_t = 3.2$, to 75% of the ultimate tensile strength of a duplicate but unplated specimen and allow the load to remain quietly for 100 hr. Specimens which were then still intact were considered satisfactory.

All specimens of consumable arc metal, 26 in number, passed this test after plating and baking in the four methods listed. Specimens plated according to Schedule No. 1 successfully endured 600 hr. loading; Schedule No. 2 successfully endured 450 hr. loading, Schedule No. 3 successfully endured 190 hr. loading, and 235 hr. for Schedule No. 4.

The air-melted metal specimens were plated according to Schedule No. 4 above (electroless nickel) and endured without fracture static loads ranging from 75% of the ultimate strength for 240 hr., to 95% for 336 hr.

Even though the induction-melted metal was not tested in this way, we conclude (having in mind extensive experiments of this sort on other steels) that 300 M steel resists hydrogen embrittlement much better than other materials classed as low-alloy, high-strength steel.

*Proportions noted are ounces per gallon.

1. High-Efficiency Cadmium Electrolyte With Brightener	
Cadmium metal	7.0 to 7.5
Free sodium cyanide	6 to 12
Total sodium cyanide	17 to 24
Sodium carbonate	2 to 4
Sodium hydroxide	3.5 to 5.0
Brightener (Rohco Super XL)	1.4% by volume
2. Standard Cadmium Electrolyte	
Cadmium metal	3.0 to 4.5
Total sodium cyanide	11.5 to 17.5
Sodium hydroxide	2.1 to 3.2
Sodium carbonate	2 to 4
Brightener (Rohco Super XL)	0.8 to 1.40% by volume
3. Chromium Plating	
Chromic acid	33 to 54
Sulphuric acid (as SO_4)	0.33 to 0.54
CrO_3 to SO_4 ratio	90 to 100
Temperature	120 to 140° F.
4. Acid Electroless Nickel Plate (Glycolate) (Units in grams per liter)	
Nickel chloride	30
Sodium hypophosphite	10
Glycolic acid	25
Temperature	190 to 200° F.
Thiourea	0.001
Sodium hydroxide to maintain pH of 4.0 to 4.5	

Endurance

Fatigue test bars were cut in a longitudinal direction from the 4 × 4-in. bar, air melted, secured from International Nickel Co. Shape and principal dimensions are shown in Fig. 4, and they were run at room temperature in a rotating beam machine with maximum stress set at various levels between 120,000 and 250,000 psi. The endurance range is shown in Fig. 5. Test pieces which were plated with 0.001-in. of electroless nickel plate broke along the left hand curve in full line. Bare metal, either (*a*) as machined or (*b*) shot-peened, then honed and electroless nickel plated, broke along the right hand curve.

Both varieties of vacuum-melted steels, in bars or slabs 4 in. thick, were tested in the short transverse direction. Shorter test pieces for rotating beam were made as sketched in Fig. 4 and tested as machined at 110,000, 130,000 or 150,000 psi. maximum. Results are shown as dotted or dashed lines in Fig. 5. There is little to choose between the two vacuum-melted varieties, although either gives a considerably better performance in bending fatigue than the basic electric steel.

Conclusions

Air-melted 300 M steel (basic electric, modified 4340 aircraft quality) in bar form appears to be a good material for use after heat treatment bringing its tensile strength up into the 270,000 to 300,000-psi. range. It contains com-

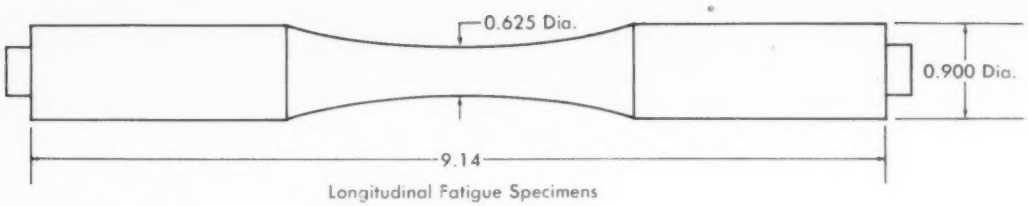
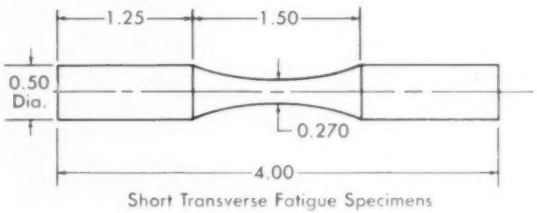


Fig. 4 – Sketch of Specimens Used for Estimating Fatigue Resistance



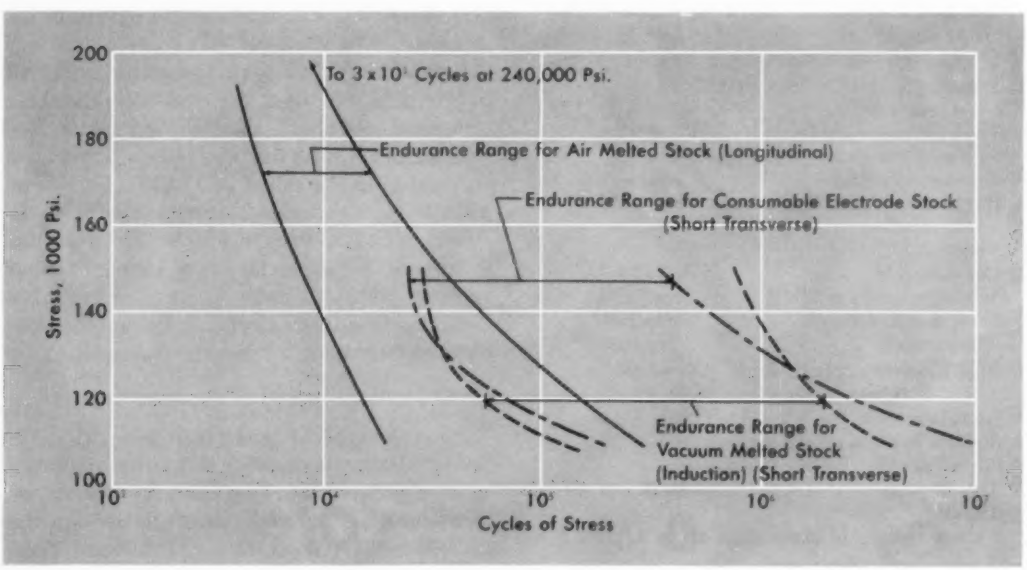
paratively larger nonmetallic inclusions, which may be responsible for the inferior ductility of tensile specimens cut transverse to the grain and for the lowered endurance limit in the rotating beam machine.

Steel melted and cast in vacuum by either method is not as free from oxide and sulphide inclusions as one would conclude from statements made in the literature. However, it has excellent combination of strength and ductility in longitudinal direction and also in transverse directions in square bars when the over-all reduction from the ingot is from 3 or 4 to 1. It can be plated and baked free from damaging hydrogen. The endurance limit of short transverse bars is somewhat lower than 110,000 psi.

Comparing vacuum steel (induction melted) with metal made by the consumable electrode method, the first is cleaner, has higher reduction of area in transverse direction, higher elongation and impact strength, and also has much better notch strength ratios. The latter can now be produced in larger ingots, is cheaper, and has slightly better longitudinal properties.

The air-melted heats studied in this work were of excellent quality. Providing that optimum reduction practices are used, we believe the greatest advantage of both induction vacuum and consumable electrode melted steel over air-melted is the uniformity of properties within heats and from heat to heat. The main reasons for anticipating improved uniformity in the vacuum-melted steels are (*a*) smaller inclusions, (*b*) better distribution of inclusions and (*c*) less gas content.

Fig. 5 – S-N Ranges for 300 M Steels Made by the Three Steel Refining Processes



Stress Analysis With a Photoelastic Coating

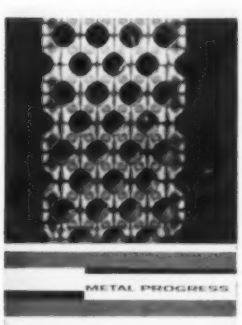
*By FELIX ZANDMAN**

Direct observation of the stress distribution of an actual part under load is possible with this coating technique. The direction and magnitude of principal stresses can be easily determined and test results can be recorded by color photography. (Q25, 1-54)

WHEN A PART COATED with a special plastic is strained, the coating follows the deformation of the part. Under polarized light, patterns or "fringes" appear which can be interpreted quantitatively in terms of principal strains on the surface of the piece. Colored fringes give the magnitude of shear strains when viewed under normal light. Oblique lighting is used to obtain principal strains. Black fringes give the *direction* of principal strains. (The color photograph on the front cover illustrates the phenomenon.) Testing with this coating – "PhotoStress", as it is termed by its developer – is equivalent to a test in which an infinite number of tiny strain gages, with virtually zero gage length, are uniformly distributed over the surface of the part.

A major advantage of the technique is that it can be applied to actual parts to be evaluated; this eliminates uncertain results obtained when testing a plastic model of the part under a simulated load. Many structures hard to measure by usual means have been analyzed with this new technique. Almost any part, made from almost any material, can be coated with plastic and tested. Direct observation of the over-all strain distribution of a part is possible under static or dynamic load conditions. Since PhotoStress is a nondestructive technique, it can be used for long periods of time in checking such structures as bridges, dams, aircraft, mine shafts, or ship hulls.

*Director of Basic Research, Tatnall Measuring Systems Div., Budd Co., Phoenixville, Pa.



On the Cover

This month's cover shows a photograph, obtained through a polariscope, which represents the stress pattern developed in a perforated aluminum plate used in heat exchangers for atomic power. The specimen has been subjected to tension loading in a testing machine. The test was performed at the Southwest Research Institute in San Antonio, by M. M. Lemcoe. The work was done for the Pressure Vessel Research Committee of the Welding Research Council to evaluate four basic stress analysis tools: Stresscoat, electrical strain gages, photoelasticity, and PhotoStress.

Note the remarkable symmetry of pattern which represents perfect axial alignment of load. The black fringes (isoclinics) indicate the directions of principal stresses; the colored fringes (isochromatics) indicate the magnitude of sheer stresses. These fringes are measured with suitable instrumentation to provide a quantitative stress analysis of the plate.

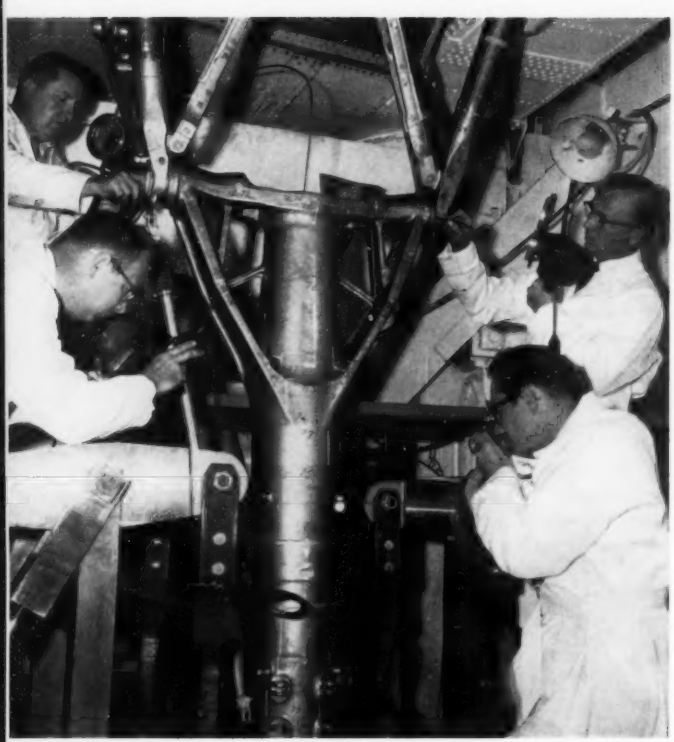


Fig. 1 – Testing Engineers Observing Strain Pattern on B-58 Main Landing Gear Under Load

Menasco-Convair Coating Procedure

Step 1. Clean and degrease the parts with acetone.

Step 2. Prepare contoured sheets of photoelastic plastic according to the following procedure:

(*a*) Pour the liquid plastic into a frame lying on a flat, horizontal plate. The amount of plastic is calculated according to the desired final thickness of the coating.

(*b*) Cure at room temperature for 2 hr. After that time, the liquid becomes partially polymerized (initial gel).

(*c*) Remove the partially polymerized sheet of plastic (which is very soft) and shape it directly on the part, leaving it in place for at least 12 hr.

(*d*) After the 12-hr. cure, lift the contoured sheet and spread reflective cement (aluminum-filled epoxy resin) on the metal part. Then bond the sheet to the part.

(*e*) Allow 24 hr. for the cement to polymerize.

When this procedure is followed, no parasitic bi-refringence will be present in the coating, and it will be of reasonably constant thickness (maximum variation, 5%). Sheets are laid side by side, as in a mosaic, to cover the desired area. Four men worked for ten days to cover the two landing gears completely. This was their first experience in applying the plastic coating.

Test Procedure Is Not Complicated

The part is cleaned thoroughly. It is then made reflective by polishing or by spraying with aluminum paint. The photoelastic plastic is applied – either as a brush-on coating or as a thin sheet bonded to the part with a reflective cement (which eliminates polishing).

After applying the test load, the surface of the part is observed through a polariscope* to check for over-all distribution of strains. Areas where color fringes are concentrated correspond to areas of stress concentration. These areas are investigated quantitatively to determine the magnitude and direction of the principal strains. (Stress values and directions of principal stresses can then be determined from these strain measurements.) Photography is used to record the position of fringes, their displacement under load, and evidence of residual strains after testing.

Limitations – Stresses cannot be measured in areas inaccessible to light. However, residual strains can be measured if a component part can be dismantled after loading and then examined under polarized light.

The strain sensitivity constant (K) varies for temperatures outside the range −44 to+85° F. Corrections of K can be made for test temperatures outside this range.

The upper temperature limit is 500° F., if testing time does not exceed 30 min. For long-term measurements, the limit is 300° F.

If the thickness of the plastic coating is comparable to the thickness of the part under test (for example, thin plates subjected to bending), errors will be introduced. Correction curves can be consulted to adjust for these factors.

Stress Analysis of Landing Gears†

Two landing gears, made of 4340 steel and 7075 aluminum forgings, were completely coated with the photoelastic plastic. (See above for coating procedure.) After mounting into frames, seven different loads were applied by

*This instrument contains an adjustable light source, a polarizer lens, and an analyzer lens.

†These tests on the main and nose landing gears of a B-58 supersonic jet bomber were performed by Menasco, Inc. for the Convair Div. of General Dynamics, Fort Worth, Tex.

Fig. 2 – The Pattern on the Photoelastic Coating Reveals Stresses Developed in a Front Axle Carrier Under 40% Vertical Load and 30° Taxi Turn Conditions. Maximum shear stress at A(6½) = ½ ($\sigma_1 - \sigma_2$) = 123,500 psi. (Arrow head representing A(6½) almost obliterates a small circle in the pattern)

means of hydraulic jacks, simulating operation of the gears in service. For each load increment, strains were measured and photographed. Figure 1 shows a portion of the gear and the loading setup.

Calibration – The average strain sensitivity of the coating is known only within 10%, and since more accurate results had to be obtained, the coating was calibrated prior to the test.

A 1-in. wide strip, cut from each sheet of plastic, was bonded to a cantilever beam where the strain was calculated at various points. The strain sensitivity was determined by applying the formula:

$$K = \frac{\delta}{2t(\varepsilon_1 - \varepsilon_2)}$$

where δ is the measured optical effect in inches, t is the thickness of the coating in inches and $(\varepsilon_1 - \varepsilon_2)$ is the calculated strain difference (in. per in.) at a given section of the cantilever beam. Based on this K-factor, 0.087, a nomograph was constructed giving the shear stress directly as a function of polariscope reading and thickness of coating.

Measurements – The directions of principal strains were obtained, within ±2°, by tracing the black fringes (isoclinics) directly on the plastic. By carefully measuring the colored (isochromatic) fringes, the magnitudes of the difference of principal strains (hence maximum shear strains) were obtained. Photographs of these fringes were taken from all sections of the landing gear. The accuracy of the strain magnitude determinations was within ±15 micro-in. per in. (or ±225 psi. shear stress).

Figure 2 shows typical isochromatic patterns on the surface of the lower axle of the main gear under a loading condition of 600,000 lb. (40% of possible load) "vertical load" and 30° taxi (plane was turning 30° while taxiing). The highest shear stress is at A, and it corresponds to 123,500 psi. Every isochromatic is a line of equal shear stress. The first isochromatic corresponds to 19,000 psi.; the second to 2 × 19,000=38,000 psi; the third to 3 × 19,000= 57,000 psi. and so on. At point A the fringe order is 6½ fringes, or 123,500 psi. Test results gave the complete stress distribution in the B-58 main and nose landing gears. It was found that loading conditions imposed the highest stress condition on the landing gear. Areas in which design changes should be made to improve stress distribution were delineated.

Future Potential for the Method

As in any strain measuring technique, photoelastic coating tests can be a part of a transducer system. A device such as a weighing system can be coated with plastic. Under polarized light, the variations in color patterns that develop during operation can be picked up by a photocell and converted into variations in electric current. The photocell output is then sent to any suitably calibrated recorder or scope.

This type of transducer system is very useful in instances where mechanical or electrical contact between the stressed part and the recording

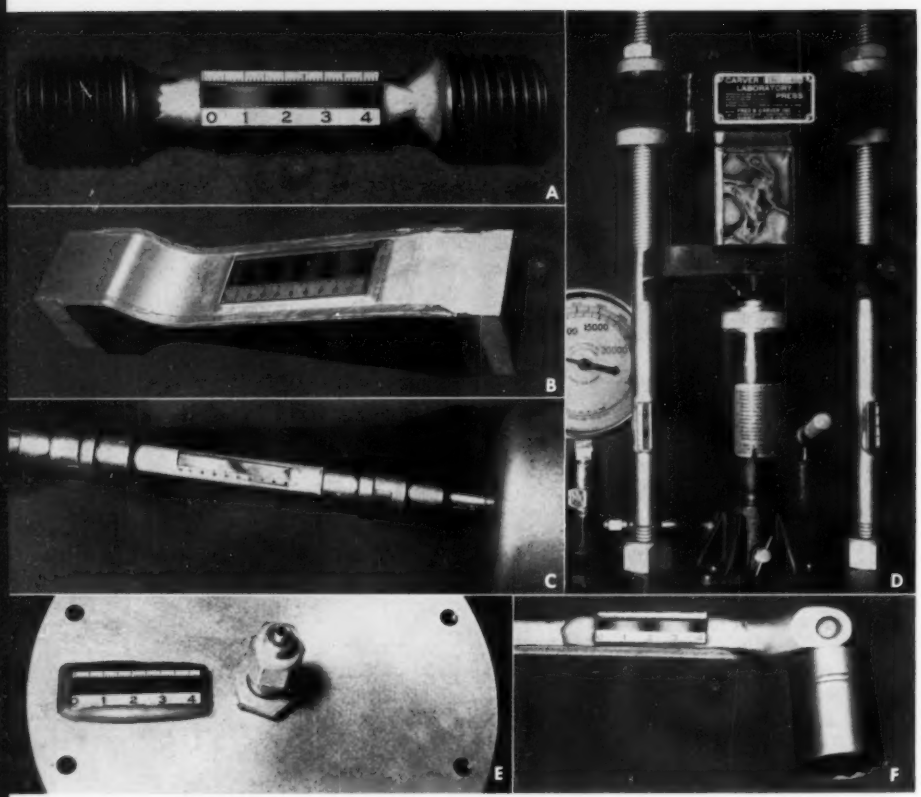


Fig. 3 – The PhotoStress Stress Gage Can Be Used as (a) a Strain Gage, (b) Load Cell, (c) Torque Indicator, (d) Safety Device, (e) Pressure Gage, or (f) Torque Wrench

instrument is impossible. As an example, a conventional torque meter requires slip rings on high-speed shafts to collect and transmit the current generated at the strain-sensing device. These rings are difficult to build and are somewhat inaccurate at best. With the photoelastic coating technique, continuous, accurate torque measurements of a rotating shaft are possible, with no physical contact between shaft and instrument. The same type of system can be used with pressure cells, load cells, extensometers or maximum stress warning devices.

The PhotoStress strain gage is a direct-reading, strain-sensitive device which requires no instrumentation. It is a small rectangular piece of plastic which shows permanent color fringes beside a graduated scale and is covered with a polarizing material. As a load is applied to a structure on which the gage is bonded, the color fringes shift to a new position on the scale. The displacement of the fringes is directly proportional to the strain. The gage can be calibrated to read directly in terms of lb. (load), in-lb. (torque), or psi. (pressure). The gage can also be employed to indicate load misalignment of mechanical presses and testing machines.

The PhotoStress stress gage, which is similar in form and behavior to the PhotoStress strain gage, gives directly the magnitude and sign of the surface stress (principal or secondary) in any required direction. A new ring-shaped gage will, in addition, indicate the direction of the principal stresses (simply note the position of maximum and minimum stresses around the gage circumference). A limitation of the gage is that it measures only average stress in the area covered by the gage and should not be used in areas of stress concentration where the application of the standard coating technique would be more appropriate. However, an attractive feature of this gage is its ability to provide direct read-out without instrumentation of any kind.

These gages can be used as permanent indicators on tools, machinery and structures. Figure 3 illustrates six applications: *(a)* as a strain gage, *(b)* as a load cell, *(c)* as a torque indicator, *(d)* as a safety device on a hydraulic press, *(e)* as a pressure gage, and *(f)* as a torque wrench.

Telemetering – A television camera can be placed behind a large-field instrument and measurements or observations made on the screen of the receiver. It is possible to investigate what is happening several miles away, in such structures as dams, bridges, missiles or aircraft in flight (or on take-off), and in atomic installations.

Applications for Photoelastic Coating Tests

Appliances and Engines

Pump for Dishwasher

Objectives: Find out why pumps were failing in service. Investigate thermal and vibratory stresses.

Loading: Pump was operated under normal conditions. Fringe patterns outlined areas of stress concentration around critical fillets of the housing. Design changes were made.

Home Radiator

Objectives: Determine reasons for rupture during service. Investigate stresses due to assembly, internal pressure, and thermal cycling. Measure residual stresses (via relaxation).

Loading: Internal pressure.

Automobile Engine

Objectives: Investigate dynamic stresses during engine operation. Check assembly (bolting sequence) and thermal cycling (35 to 100° F.)

Loading: Operate engine under normal conditions (200° F. engine temperature).

Aviation

Jet Fighter Fuselage

Objectives: Locate stress concentration in fuselage near engine mounts. Measure stresses around highly loaded rivets.

Loading: Engine weight is combined with external forces applied by hydraulic jacks to simulate quick transition from horizontal to vertical position.

Fuselage Panel Assembly (With Stiffeners)

Objectives: Check stress pattern and behavior of rivets during break-in period. Study elastic and "elasto-plastic"* buckling. Study dynamic buckling by taking color motion pictures of fringes. Obtain residual strain pattern after panel ruptures.

Loading: Compression.

High-Altitude Tests on Airframe

Objectives: Measure strain (*a*) on window and sash subjected to internal load produced by cabin pressurization, (*b*) on fittings which attach wings to fuselage, and (*c*) on external wing rivets.

Loading: In-flight tests at 36,000 ft. Measurements also made during a dive and a rough landing.

Guided Missile Tail Section

Objectives: Determine over-all stress distribution and measure peak stresses. Investigate effect of stiffeners on stress distribution of the skin and determine when localized buckling begins.

Loading: Static and dynamic loading with hydraulic jacks to simulate flight conditions.

Landing Gear

Objectives: Find over-all stress distribution under various landing conditions.

Loading: Static loading with hydraulic jacks to simulate landing conditions.

Photograph below is a general view of test setup, showing landing gear, loading frame and measuring instrument.

Riveted Airframe Assembly

Objectives: Compare designs of riveted assemblies and study stress at each rivet. Evaluate effect of dummy rivets located near edge of assembly.

Loading: Tension

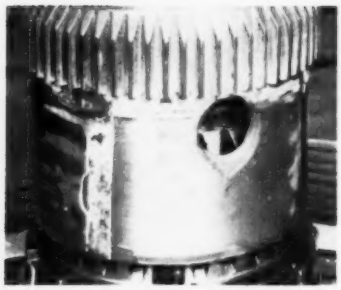
Splined Coupling for Jet Engine

Objectives: Study distribution of elastic, elasto-plastic and residual strains in vicinity of grease hole and find stress concentrations around splines. Check theoretical calculations against experimental results.

Loading: Torsion.

Photograph on top p. 116 presents view of coupling with a contoured sheet of plastic in place.

*If a long, rectangular sheet with a hole in its center is tensile tested, the area around the hole will yield plastically before the rest of the sheet. At this point the entire specimen is undergoing elasto-plastic strain.



Turbine and Compressor Blades

Objectives: Determine stress concentration on leading and trailing edge and find yield point of blade. Study behavior of various blade footings and locate stress pattern around points of corrosion.

Static loading: (*a*) in tension, (*b*) bending plus tension, and (*c*) tension plus torsion.

Dynamic loading: Bending in a fatigue machine and bending in natural mode of vibration.

Jet Engine Combustion Chamber

Objectives: Determine over-all stress distribution and yield point of chamber. Study plastic deformation and behavior of welds under stress. Measure residual strains after failure.

Loading: Internal pressure.

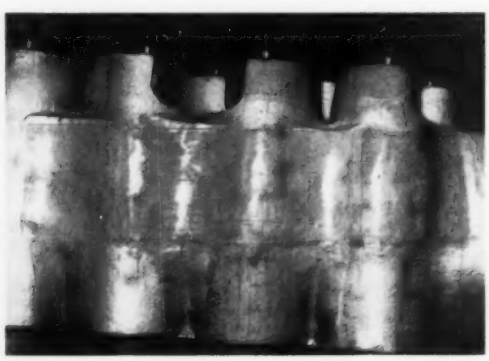
Atomic Energy and Pressure Vessels

Flow Header

Objectives: Determine area where structure must be reinforced and where it is unnecessarily strong.

Loading: Varying amount of internal hydrostatic pressure.

Photograph below is over-all view of flow header showing coating and points investigated.



Heat Exchangers

Objectives: Locate stress concentrations and study over-all stress distribution. Find yield point and investigate elasto-plastic deformation. Proof-test before shipment.

Loading: Internal pressure.

Model of Atomic Energy Pressure Vessel

Objectives: Determine stress distribution at welds and over-all – for use in full-scale design.

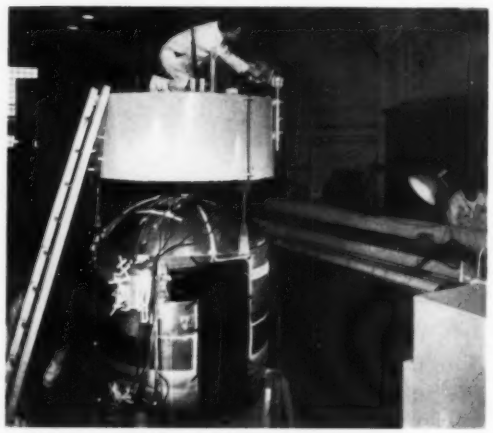
Loading: Axial loading with hydraulic jacks.

Fuel Container for Solid-Fuel Rocket

Objectives: Study stress distribution and determine stress concentration around welded sections.

Loading: Internal pressure.

Photograph below shows over-all view of test. Note automatic high-speed movie camera, at top, which records changing PhotoStress pattern.



Railroads

Railroad Rail

Objective: Determine stress distribution and yield point on a rail and a rail end as radius of test wheel is varied.

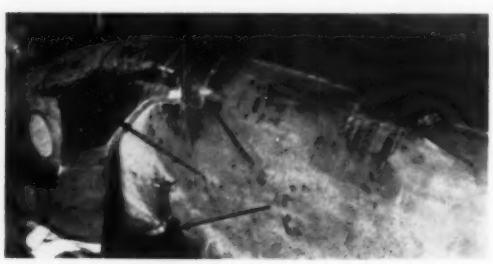
Loading: Compression and bending by means of steel railroad car wheels of various sizes.

Truck Frame

Objectives: Determine stress concentration factors around welds and fillets, and stress distribution in known dangerous areas. Check PhotoStress results against conventional strain gage results.

Loading: Compression and bending by means of vertical, horizontal, lateral and combined loadings with hydraulic jacks.

Photograph below shows partial view of truck frame. Arrows indicate location of plastic.



Mild Steel Beams for Railroad

Objectives: Calculate strain concentration factors in vicinity of load contact points. Locate neutral points in beam and observe shift during plastic flow.

Loading: Bending (statically indeterminate).

Inspection of Structures – Testing of Materials

Arc Welded Steel Bridge Assembly

Objectives: Find general elastic stress distribution; then find yield point near welds and study elasto-plastic deformation. Investigate influence of welds on stress distribution. Check PhotoStress results against calculations and against strain gage results.

Loading: Bending by means of hydraulic jacks.

Inspection of Canal Locks

Objectives: Investigate stress concentration around rivets and study stress distribution in suspected critical areas. Repeat measurements at regular intervals.

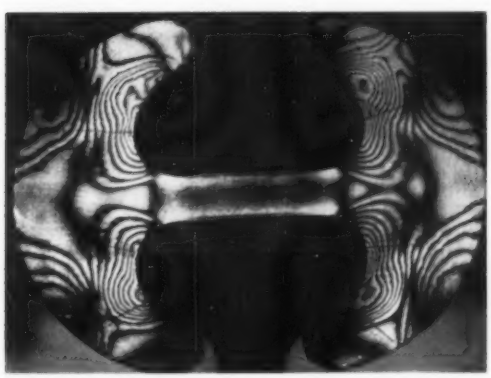
Loading: Obtained by filling chambers with water.

Sheet Pile Section for Coffer Dam

Objectives: Determine maximum service load in elasto-plastic range of deformation. Investigate elastic strain distribution and find yield point. Compare merits of different designs.

Loading: Tension applied by means of a testing machine.

Photograph below shows a stress pattern produced by a load of 6000 lb. on the sheet pile.

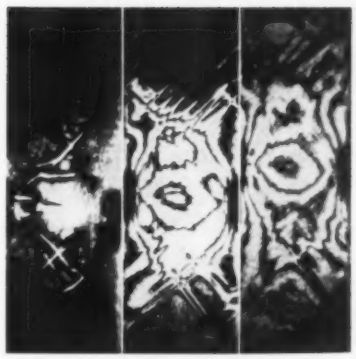


Testing Mild Steel Specimens

Objectives: Determine true yield point and study plastic deformation.

Loading: Tension (semicircular notches cut in test specimens).

Photograph at top of next column reveals three stages of plastic deformation: (Left) True yield point – 30% lower than the value obtained by conventional methods. (Center) Conventional yield point. (Right) Well beyond yield point.



Welding

Stainless Steel Spot Welded Assembly

Objectives: Determine best arrangement for spot welds – in terms of number, spacing, and rows – consistent with a rational distribution of stresses.

Loading: Tension. (Test results indicate first row of spot welds carries practically the entire load.)

Two Aluminum Plates Welded at Right Angles

Objectives: Determine internal stresses via stress-relieving (progressively machining down one of the plates).

Steel Bottle With Welded Neck

Objectives: Study stress distribution and plastic deformation around welds. Determine elastic limit resulting from combination of internal stress due to welding and stress caused by pressure in the bottle.

Loading: Internal pressure.

Butt Welded Specimens

Objectives: Determine best method of stress-relieving and find area affected by internal stress due to welding.

Loading: Tension. Identical welded specimens were stress-relieved in different ways and then subjected to a tensile stress slightly higher than yield point of base metal.

Circumferential Weld on Steel Cylinder

Objective: Measure internal stress.

Test Procedure: After coating with plastic, sections of the cylinder are cut out and metal removed from welded area. The stress distribution in the section – caused by stress-relaxation when weld metal is removed – corresponds to internal stress distribution when weld existed (the sign of the stresses is reversed).

Ordnance Applications

Armaments

1. Study armor plate during perforation.
2. Find stress distribution in firearms during firing.
3. Investigate stresses in guided missiles developed during firing and in flight.

*The A.E.C.'s Power Program**

The short-range objective of the Governmental program for nuclear reactor development is to enable American utility companies (between now and 1968) to select large power plants on the basis of economics alone in areas where fossil fuel costs are 35¢ per million Btu. or higher.

Reactors cooled and moderated with light water, fueled with slightly enriched UO_2 clad in stainless steel or zirconium, and which produce saturated steam for the turbines, have the best developed technology and are closest to meeting this short-range objective. Such pressurized or boiling water reactors under private financing could produce power costing from 9 to 10 mils per kw-hr. in 300,000-kw. plants and, through improvements that are clearly feasible, units could be constructed in 1963 to 1965 which would produce power costing from 7 to 8 mils.

Since conventional power under the same conditions of financing would cost from 6 to 7 mils from fuel costing 35¢ per million, it can be seen that water reactors almost meet our short-range objective, and their true potential has not been fully recognized.

The possibilities of nuclear superheat and of steam-cooled systems remain to be determined. Simplified control by varying the level of the moderator in the reactor, improving the neutron economy by proper mixture of light and heavy water used as moderator, improving the mechanical details, operating at higher power density – all these are improvements for the future.

It is indeed fortunate that the technical variables of fuel life and cost of fabrication, over which industry has control, are relatively more important than the aspects over which the Government must retain control. I refer to the fact that by law the Government fixes the cost of U^{235} and credit for any unburned portion, as well as for the U^{233} and Pu which may be produced and the charges for processing the spent fuel. Moreover, if the reactor uses heavy water as a moderator, the owner is dependent on Government supply at the Government's price. It may be stated that these charges represent neither a subsidy nor a source of profit. In our planning (based on plants of about 300,000 kw-hr. capacity), we assumed private financing and annual fixed charges of 14% for both conventional and nuclear plants, and water-moderated reactors will meet the short-range objectives in reactors of large sizes.

Our longer-range objective is to enable all utility owners to choose a *nuclear reactor* for a source of heat regardless of location or size of plant. Whether water-moderated reactors can also meet this goal is a matter of opinion (and our current studies indicate a marginal likelihood that they can) but we are studying small prototypes utilizing other principals.

The organic cooled and moderated reactor is similar in many respects to the water system, yet operates at lower pressures and has fewer corrosion problems. Its advantages are somewhat offset by the fact that the organic materials now available are polymerized by radiation and must be continuously replaced, and that the heat transfer characteristics are not good.

Obviously our program must also encompass other systems which will give the higher temperatures necessary for modern steam conditions, offer higher neutron economy, and be built at a lower cost because they have higher power densities or simpler design, or which have lower fuel, operation or maintenance costs. We are interested in gas, liquid metal, and molten salt systems because they offer the high-temperature steam conditions needed for greater plant efficiency. We are interested in certain gas and liquid metal systems. We are interested in molten salt, aqueous homogeneous and some variations of liquid metal cooled systems because they offer the potential simplifications inherent in fluid fueled reactors. We are interested in gas and liquid metal cooled systems because they promise a more uniform burnup of the fuel or simplified recycle of unburned fuel.

The total cost of our program will be about $1,800,000,000 over the next nine years, which will include about $1,400,000,000 for research and development and $360,000,000 for 14 prototype and six experimental plants.

If our efforts were to succeed merely in lowering the average cost of power in America by one tenth of a mil, consumers would save $200,000,000 in that year alone.

*Extracts from an address by F. K. Pittman, director of division of reactor development, U. S. Atomic Energy Commission, before World Power Conference, Madrid, Spain, June 8, 1960.

Electronic Metallurgy

*By HARVEY A. ANDERSON**

The electronic industry, based on semiconductors, is growing at such an astonishing rate that it has outrun the available supply of metallurgists and solid-state physicists. Furthermore, quality control has all but outrun the ability to measure micro differences in the materials of construction. (T1, 17-57; EG-j, Si, Ge)

IT IS SIGNIFICANT that at the 1960 Annual Stockholders' Meeting of General Electric Co. it was stated that the most important phase of G.E.'s activity today from a growth standpoint is in the electronics field and that its most important product in that field is semiconductors. Ever since 1948, when Bell Telephone Laboratories announced the discovery of transistors (a discovery which warranted the Nobel prize in physics to William Shockley, Walter H. Brattain and John Bardeen), the growth of semiconductor technology and production has been phenomenal – only outpaced by the skyrocketing of the electronic shares on the stock market!

It is fitting therefore that *Metal Progress* should print a brief statement of the present situation as gathered in recent meetings and symposiums held by the A.I.M.E.'s Metallurgical Society, by New York University, and by the American Society for Testing Material's Committee F-1. It will avoid the physical and electrical jargon as much as possible. Those readers who are not very familiar with the topic could do no better than refresh their memories by reading Anthony S. Rugare's articles on germanium and silicon for electronic devices in *Metal Progress,* August 1952 and February 1955.

*Electronic Consultants, Inc., Tucson, Ariz.; Consulting Editor, *Metal Progress.*

The Industry and Its Needs

In this age of television, radar, computers, and missiles, metallurgy is acquiring what is almost a new "micro dimension" to provide the materials essential for satisfactory functioning of the electronic devices. An evidence of maturity is A.S.T.M.'s recently established Committee F-1 on Materials for Electron Tubes and Semiconductor Devices. The unique requirements of the manufacturers of electronic devices have necessitated new standards for internal and surface purity, alloying, grain size and orientation.

There are now at least 40 American firms making transistors to a total of around 2,000,000 annually, with additional production of a much larger number of diodes. In this industry the demand for competent metallurgists far exceeds the supply – as anyone who scans the help wanted pages in *Metals Review* will appreciate. Perhaps the demand is really for "scieneers", as *Engineer* paraphased the remarks of Bell Telephone Laboratories' J. R. Pierce at the

recent conference at New York University on "The Critical Million", where the need for more communication between scientists and engineers was emphasized. However, the qualifications outlined in two recent advertisements of semiconductor manufacturers for metallurgists included a Ph.D. or M.S. degree or equivalent experience in physical metallurgy or solid-state studies, to assist in the development of micrometallurgical techniques under protective atmospheres, vacuum deposition of high-purity metals, and recrystallization of rare metals during alloying and welding on a subminiature scale.

In electronic metallurgy, as in more conventional types, metal behavior is dependent on its intrinsic properties and its environment. However, the difficulties arise in defining, appraising and controlling the unique properties, and the greater sensitivity to environment which is encountered when the semiconductors are fabricated into electronic devices. Semiconductor manufacturers are among the growing class of metallurgical customers which cannot depend on the metal manufacturer or fabricator to solve customers' problems with existing metals and alloys.

Purity in Parts per Billion

Transistors are solid devices made from semiconductors – metalloids whose electrical resistivities are between that of metals (low) and of insulators (very high). The most common elements are germanium and silicon. In one method of manufacture, crystals are grown and then purified by zone melting. In the early days, germanium transistors had point contacts somewhat like the old cat's-whisker crystal radio sets. Subsequent technical developments have produced grown-junction transistors, alloy transistors, and diffused transistors. Still other types are being developed. In all of them the properties are dependent on an atomic dispersion of very small amounts of impurities and on imperfections in the crystalline lattice.

The electronic metallurgist faces the problem of controlling, to an unusual degree, the purity and structural perfection of semiconductor crystals. S. Wolsky of Ratheon called the attention of the A.S.T.M.'s Committee F-1 to the use of a vacuum microbalance and an "omegatron" mass spectrometer* in the study of atomically clean surfaces of germanium and silicon single crystals in wafer form, 2 to 4 mils thick and less than 10 sq.cm. in area. With these techniques we can study, quantitatively, the effect of such operations as out-gassing, oxidation, ion bombardment, and sputtering rates. Such matters are important, for the operating characteristics and permanence of transistors are dependent on the crystal's oxidized surface, about 10 atom diameters thick, and the production of reliable transistors of high quality necessitates final surface treatment and encapsulation in nonporous envelopes – operations representing a major part of the unit's over-all cost.

Semiconductor devices in the electronic field include, in addition to transistors with three or more terminals, diodes for rectifiers and mixers (with two terminals), solar cells, voltage variable capacitors, and numerous others. Recent developments involve combinations of several units with varying functions in compact assemblies, fixed in place within a molded block of plastic.

It has been stated repeatedly that progress in the semiconductor field is based on progress in materials – the metals and alloys. The original point-contact transistors used multicrystalline germanium but were somewhat undependable. Most transistors are now made of germanium single crystals with rigidly controlled impurity content. The perfection of the material has nearly outrun the possibility of physical measurements, in the same way that chemical purity far outran chemical analysis long ago.

The much more abundant silicon is starting to overtake germanium as the favored transistor material, even though its crystal growth and zone refining present many more problems, due to its high melting point and its tendency to react with any type of refractory container. Transistors are also being manufactured of germanium-silicon, gallium arsenide, and numerous other alloys of metalloids in and about Group IV of the periodic table.

*When asked by the editors to define "omegatron mass spectrometer", Mr. Anderson replied:

"The partial pressure of residual gas in an ultra-high vacuum system is an important influence on its behavior and dependable life. The 'omegatron' is a new device for gas analysis. It is an ionization tube of small volume and operates at elevated temperatures. It uses the cyclotron resonance principle of the motion of an ion in crossed electrical and magnetic fields to identify gaseous constituents at very low pressures – 10^{-5} to 10^{-10} mm. Hg.

"The need for this definition well illustrates the interrelation of modern metallurgy, chemistry and solid-state physics in this new science of electronics."

Book Review

Malleable Iron Castings

*Reviewed by CARL F. JOSEPH**

MALLEABLE IRON CASTINGS, Malleable Founders Society, Cleveland, 1960. 526 p. $10.

FROM AN INDUSTRY initially surrounded by secrecy and mystery, an organization began which became one of the first cooperative industrial groups in the United States. In 1897, the American Malleable Castings Assoc. was founded to share knowledge of practice, and thereby improve the product. Today this group is known as the Malleable Founders Society, and it is to them that we are indebted for this book.

Malleable Iron Castings replaces the original handbook, American Malleable Iron, published in 1944, and fills a long standing need for an up-to-date reference on this subject. The book is primarily one for users of castings rather than producers. However, it has considerable value for those in the industry as well since much of the information which is widespread throughout the technical literature is made available in one volume.

The many uses for the various grades of malleable iron and the inroads made into new fields, particularly highly stressed parts, are exemplified in the first chapter. The expansion of the product has been primarily due to increased use of pearlitic malleable iron in parts previously made of steel, such as crankshafts, universal joint yokes, rocket arms and many automotive transmission parts. This is reflected in the chapter on pearlitic malleable iron – it has been expanded from eight pages in the original publication to 40 pages in the current one.

A fairly comprehensive treatment of physical and mechanical properties of standard and pearlitic malleable iron is given in three chapters. This is essentially a collection of independent studies. The tying together of related investigations of properties has been well done considering that compositions and foundry practices are far from uniform.

The chapters on design and machining should be of particular interest to the user of malleable iron castings. It is only through knowledge of the capabilities of the foundry that the fullest advantages of malleable iron castings can be appreciated. Written in an instructive and practical manner, these chapters should give the potential user a basis for an intelligent approach to applications for parts made of malleable iron.

The discussion of manufacture of malleable iron has been expanded considerably from the original text. The tremendous strides made in modernizing the foundry industry over the past sixteen years is illustrated by the transition from bench molding, floor pouring, and batch-type annealing to mechanized molding, including shell process, duplex melting, and continuous pouring and annealing.

While the metallurgy of malleable iron has actually changed very little over the years, our knowledge of it has increased substantially. Of significance is the influence of various trace elements on mottle and annealability. Among these are the intentional additions of bismuth and boron to prevent mottle and shorten annealing time. Considerable information concerning various heat treatments and resulting microstructures and properties, as well as common alloying elements to improve strength and hardenability, is given.

A fine set of references has been included which should give the interested engineer or metallurgist ample information for the further study of malleable iron.

*Technical Director, Central Foundry Div., General Motors Corp., Saginaw, Mich.

Short Runs

Navy Picks Cast Stainless Alloy

*By E. A. SCHOEFER**

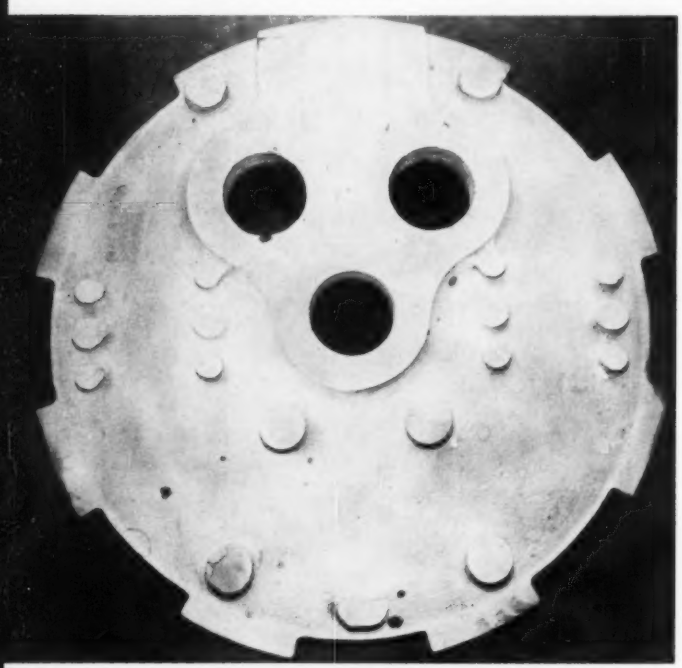
IN RECENT YEARS a great deal of foundry research has centered around the development of new alloys to meet the increasingly severe conditions of new industrial processes.

A good example of the progress being made is CD-4 MCu, a precipitation hardenable stainless casting alloy which contains 25 to 27% Cr, 4.75 to 6.00% Ni, 1.75 to 2.25% Mo, and 2.75 to 3.25% Cu. It was developed under a program sponsored by the Alloy Casting Institute to find an alloy with the corrosion resistance of the 18-8 grades but with much higher strength.

As reported in *Metal Progress* (October 1958, p. 129), the strength of CD-4 MCu is about twice that of the standard 18-8 alloys. Recent experience has revealed an unanticipated bonus. The cast alloy's resistance to stress-corrosion is superior to that of the wrought 18-8 grades – both the ordinary Type 304 and the molybdenum-containing Type 316. In recent tests made by the Sharples Corp., Philadelphia, CD-4 MCu in the hardened condition (solution annealed for 2 hr. at 2050° F., oil quenched; aged 4 hr. at 975° F.) sustained a stress of 62,000 psi. without cracking when exposed to boiling 42% $MgCl_2$ for 100 hr. Annealed Type 316 cracked at 8000 psi. and annealed Type 304 cracked at 12,000 psi. Wrought Type 310 failed at 35,000 psi.

*Executive Vice-President, Alloy Casting Institute, Garden City, N.Y.

Fig. 1 – Torpedo Tube Breech Door Weighing 250 Lb. and 26 In. in Diameter Was Cast of CD-4 MCu Precipitation Hardenable Stainless Alloy for Nuclear Submarine SS(N) Thresher. To meet Navy requirements, castings were subjected to 100% X-ray inspection, Class II, and dye penetrant inspection performed in accordance with MIL-STD-271. Typical mechanical properties were 110,000 psi. tensile, 85,000 psi. yield, 25% elongation and Charpy impact (V-notch) 40 to 50 ft-lb.



Torpedo Tube Breech Door

Confirmation of these results has come from engineers at the Portsmouth Naval Shipyard, Portsmouth, N.H., who recently concluded a one-year corrosion test program. CD-4 MCu and several other alloys such as Type 304, nickel-copper and aluminum bronze were subjected to tests in running sea water in a variety of setups designed to determine resistance to galvanic, crevice, and stress-corrosion. Corrosion resistance of CD-4 MCu was better than any of the other alloys. In stress-corrosion tests lasting six months, no failures occurred in either hardened or annealed CD-4 MCu.

As a result of these tests, the breech door of a new type of torpedo tube assembly (Fig. 1) for the new Thresher-class nuclear attack submarines was cast in this alloy. The SS(N) 593 Thresher, lead boat of a group of 14, was launched at Portsmouth last summer.

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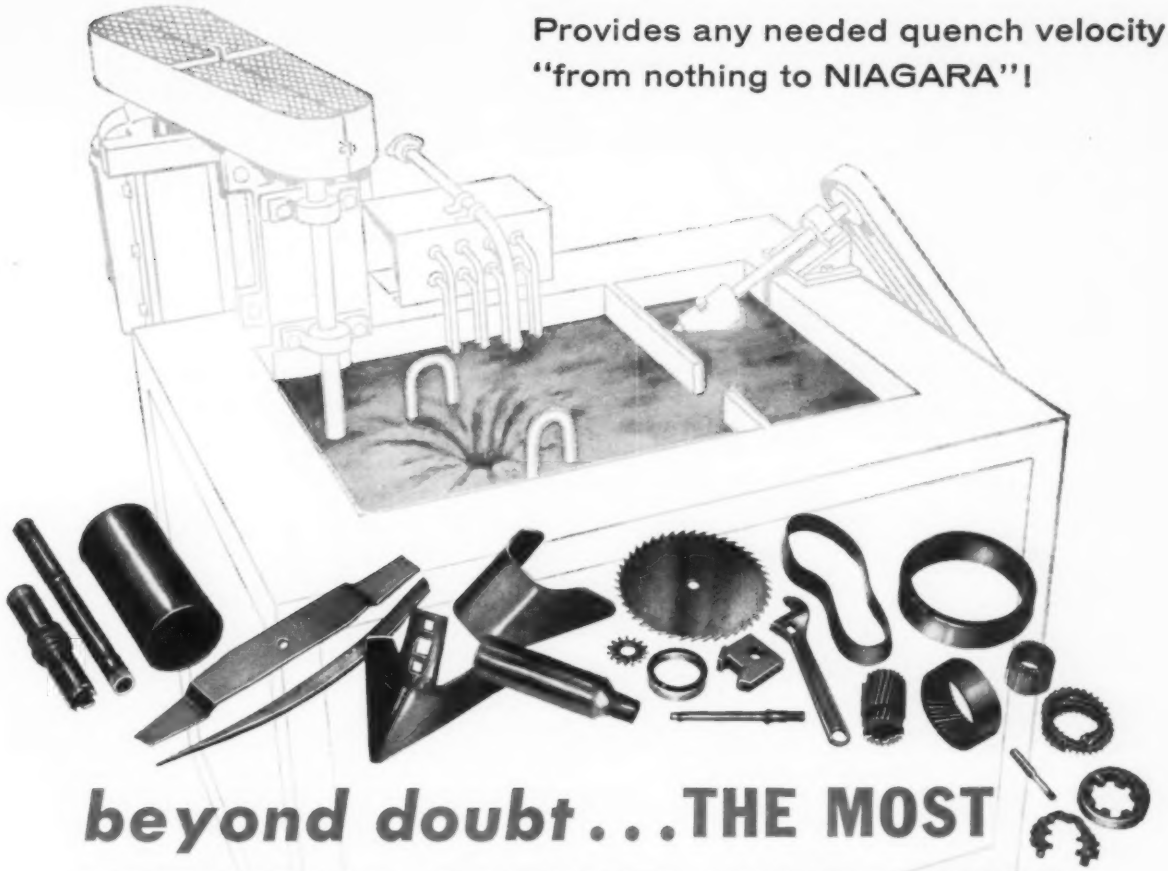

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AJAX ELECTRIC COMPANY 910 Frankford Ave. Philadelphia 23, Pa.

Circle 1993 on Page 48-B

CORRESPONDENCE

Trends in Price of High-Alloy Castings

GARDEN CITY, N.Y.

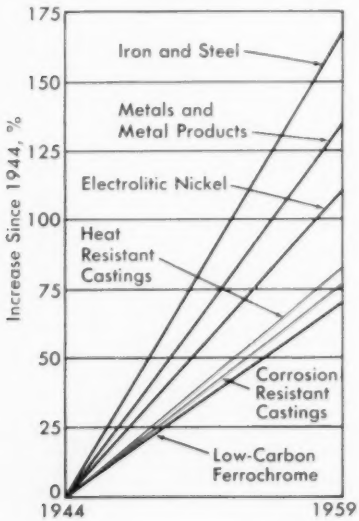
The "Technical News" item on p. 67 of your September issue entitled, "Up Trend in High-Alloy Castings Levels Off", draws an unjustified conclusion regarding the status of the high-alloy foundry industry. Based on our 32-p. Statistical Review of 1959, "Production of High-Alloy Castings", the short article concludes that the growth of the high-alloy casting industry has leveled off, and implies that "perhaps this is due to the increase in price".

Let us look at the facts: During the interval 1944 to 1959, mentioned in the article, alloy casting prices increased from $0.60 to $1.15 per lb., as stated, a rise of 92%. During the same period, iron and steel prices as a group (Bureau of Labor Statistics data) rose 168% and metal products in general went up 137%. As shown in the accompanying chart, the change in alloy prices has been less than the rise in raw material cost.

It is improper, therefore, to assume that the current drop in high-alloy casting shipments is a permanent departure from the past uptrend in demand as a result of an excessive rise in price. There is no evidence that present slack business will not be followed by a resumption in normal growth. On the other hand, there is evidence that if prices for alloy castings have gotten out of line, they are out of line on the low side compared with the rise in the prices of other metallic products.

E. A. SCHOEFER
Executive Vice-President
Alloy Casting Institute

Change in Price of Alloy Castings Compared With Other Metal Products in the Period 1944 to 1959



Chromium Steels in Refinery Service

NEW YORK

Mr. Scheil and his firm deserve thanks from the petroleum industry for conducting the ten-year test of high-chromium steels and for publishing the results in *Metal Progress*, April issue. Unfortunately the title* of the paper "Chromium Steels Remain Tough After Eight Years at High Temperatures" implies that *all* of the chromium steels in the test resisted high-temperature embrittlement satisfactorily, whereas the Type 405 steels designated as Code D, F, and H (decarburized) all tended to serious embrittlement.

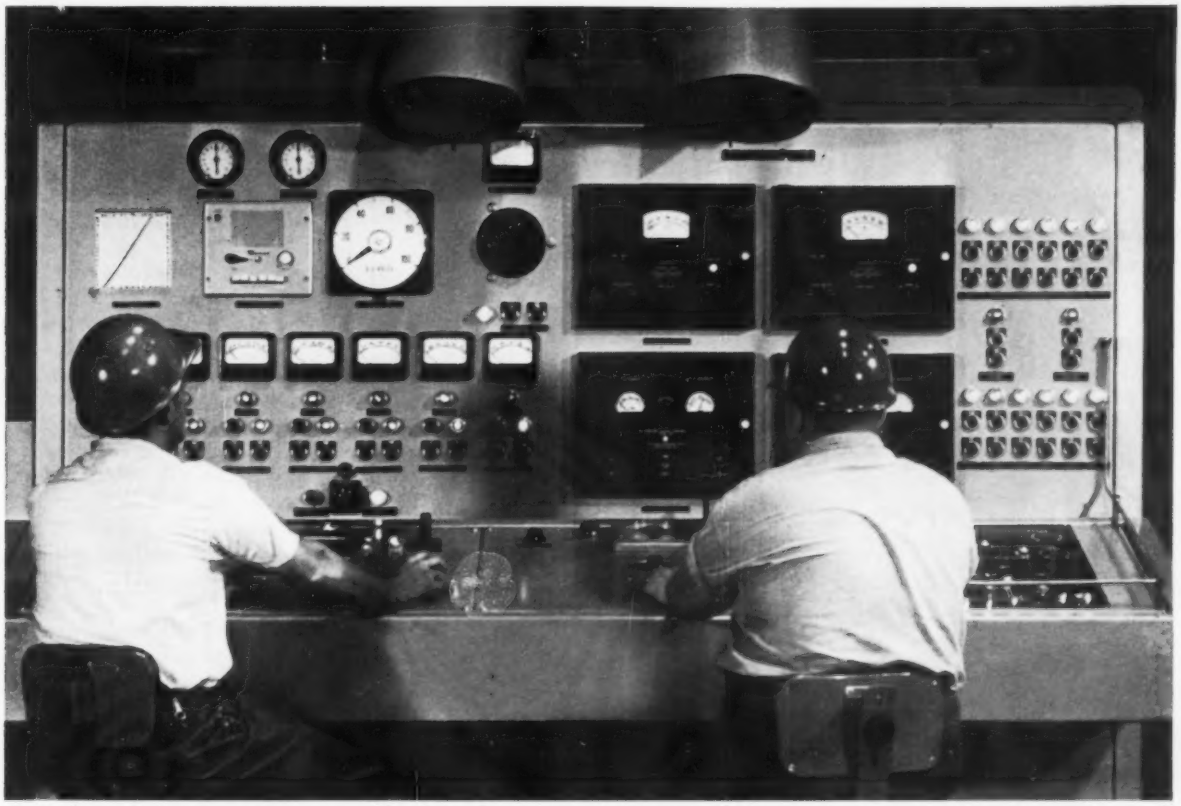
The D and F steels suffered drastic loss of impact resistance as measured by the Charpy test – especially in the initially annealed or in the annealed and cold worked conditions; after exposure at 715° F. for six years these alloys showed only 2 to 6 ft-lb. impact energy when tested at 70° F.

The decarburized Code H steel was only exposed at 900° F., but after eight years its original 56.4 ft-lb. had fallen to 9. These three steels all have high chromium equivalents, and this tends to confirm the suspicion that the more completely the alpha-gamma transformation is suppressed in Type 405 steels, even with the help of minor additions of aluminum or other ferrite-forming elements rather than by chromium alone, the more susceptible they are to 885° embrittlement. In other words, the more they transform at high temperatures, like the old 17% chromium-iron Type 430, the more they tend toward age-embrittlement at 700 to 900° F.

Mr. Scheil admits that the evaluation system used in his paper gives three times as much weight to changes in other properties (yield, elongation and hardness) as to a decrease in impact energy (tested at 70° F.) but believes that skeptical readers making their own assessments will come to conclusions similar to his. I have come to conclusions that differ from his. I think that the magnitude of changes in the impact values are the most significant indication of embrittlement, in his data, although I recognize that impact tests do not reflect *all* types of brittleness. (I would define "embrittlement" as the development of brittleness in a metal, and "brittleness" as the tendency of a material to fracture with little deformation.)

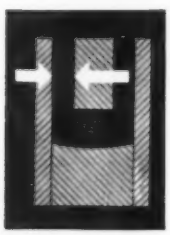
When examined from this viewpoint, some curious anomalies exist in the tables. For example, the one Type 410 steel of normal analysis (0.07% C, no Mo) was exposed at 715° F. only in annealed condition. It is rated "poor" by virtue of modest change in yield, elongation

*The title was supplied by the editors. The word "which" should have appeared after the word "steels".



Control panel of a Carpenter consumable electrode (Consumet) furnace. Electronic circuits maintain positive arc control and precise electrode movement to assure the ultimate in refining.

Where *Carpenter's* "big inch" makes a mile of difference in alloy quality



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Circle 1994 on Page 48-E

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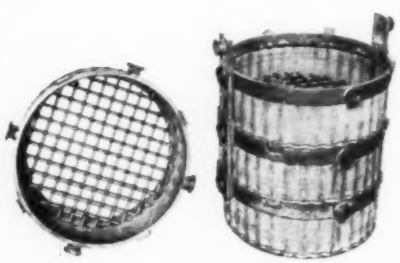

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Circle 1995 on Page 48-B

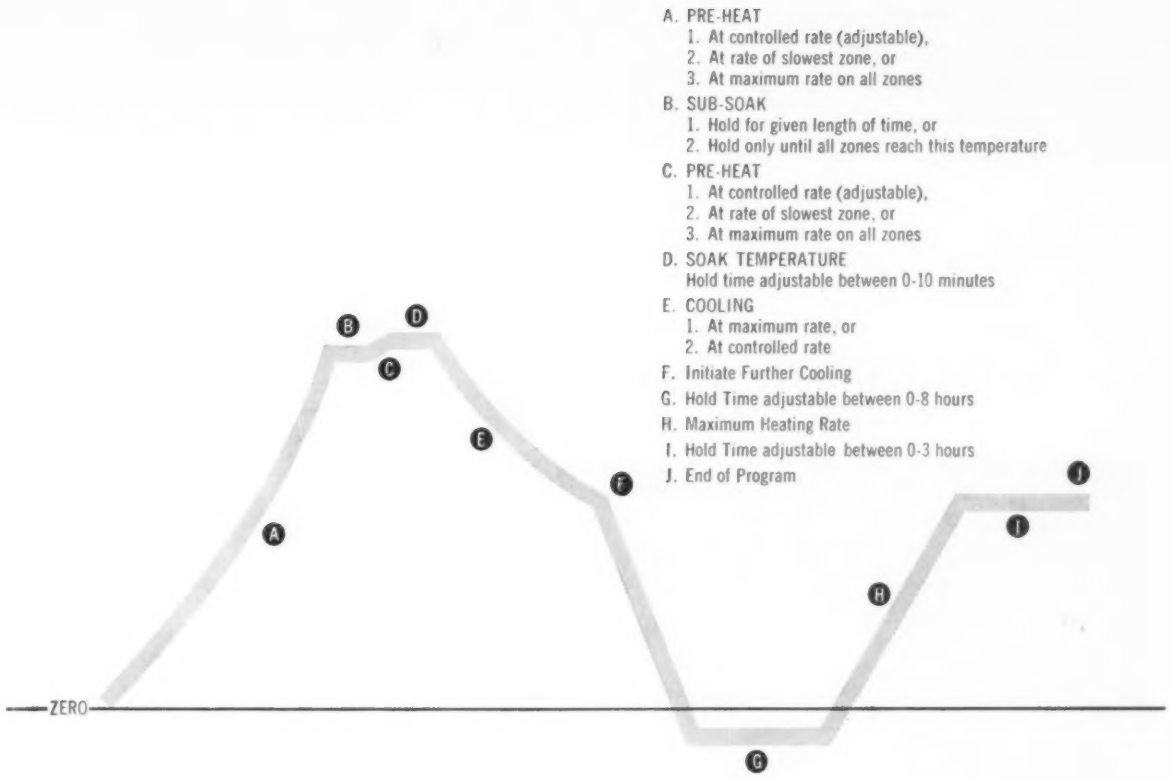
Correspondence . . .

and hardness, yet its original Charpy value of 56.5 ft-lb. remained unchanged after two years at 715° F. and dropped only to 36 after six years (impact tests at 70° F.). The latter figure is the second best of all values for the Series 400 steels at the end of their exposures at 715° F. Another example is a type 405 steel (Code D, Treatment III, giving a coarsened grain) which is rated as "good" after six years at 715° F. by virtue of only small changes in yield, elongation and hardness, yet its original impact value of 5.1 ft-lb. (quite low) was reduced to only 2 ft-lb. at the end of the test.

Since the field tests now reported by Mr. Scheil were started, instances of embrittled Type 405 steel in refinery equipment have been turning up periodically. His new data show that this is to be expected of some heats of this alloy, but that others can be expected to resist embrittlement quite satisfactorily. I believe that his paper would have been more helpful if it had shown how specifications should be modified so as to obtain a nonembrittling Type 405 steel. This is the kind of information the petroleum industry and other users need. They also require assistance from fabricators like A. O. Smith Corp. in seeing to it that steels conforming to such specifications are obtainable from the steel industry. There is no need either to condemn or defend *all* Type 405 steels.

R. W. Manuel
Engineering Department
Socony Mobil Oil Co., Inc.

Mr. Scheil's Reply — Apparently the major difference between Mr. Manuel and me is that he wishes to rate the steel's embrittlement primarily on the 70° Charpy impact values. I will not argue that point, other than to say that I think the standard tensile test is of much importance to designers, and that the yield and elongation of those steels and conditions graded "good" to "excellent" after the long-time tests were not altered to a disturbing degree. I would also state that these tests were planned 12 years ago and that we did not have unlimited material to test or means to expose. In the intervening time, other appraisals of "embrittlement" than



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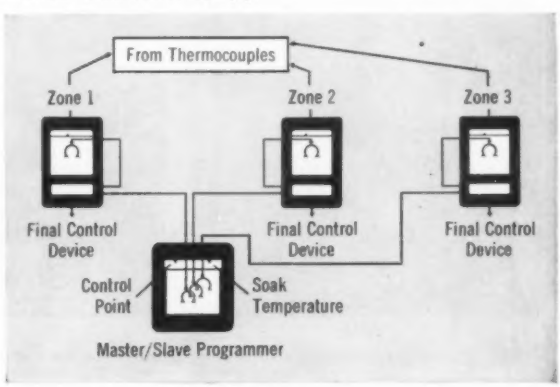

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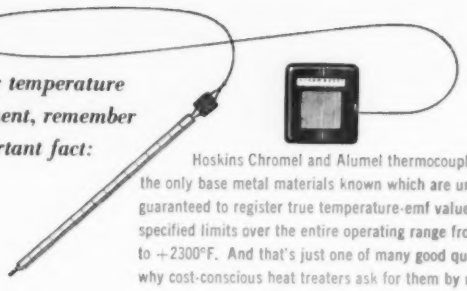

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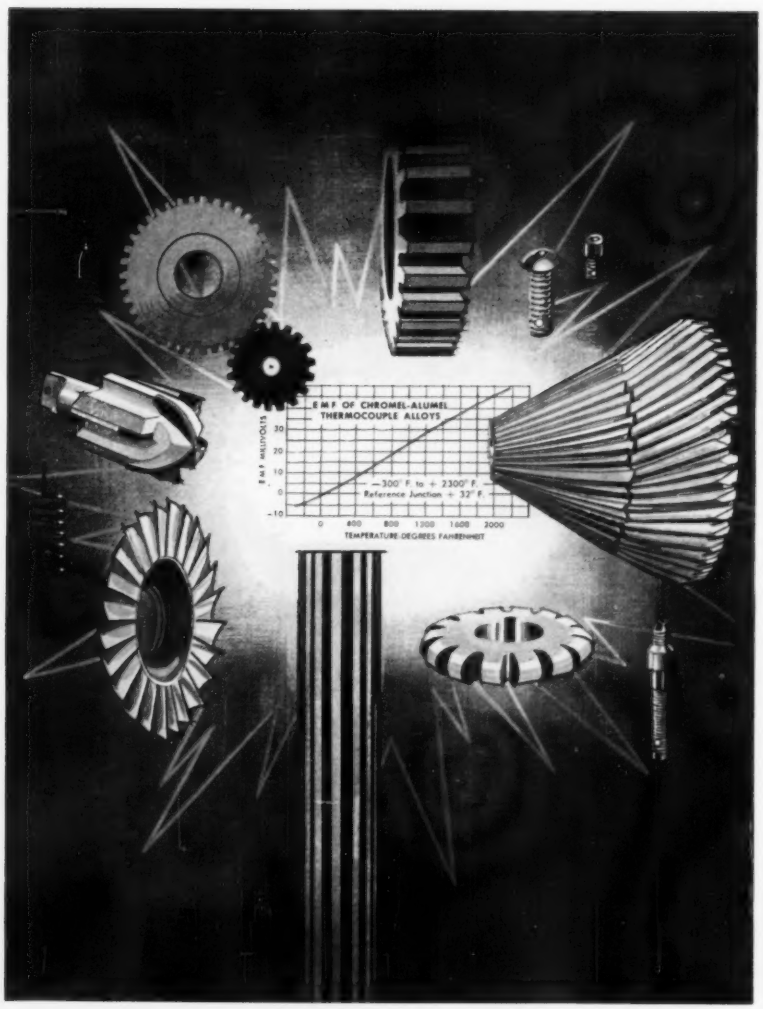

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Circle 1997 on Page 48-8

Correspondence . . .

room-temperature Charpy values have been proposed by investigators, and received much support. In the original article, at bottom of p. 109, I say:

"We now know that a more concise method of evaluating the aging effect on notch toughness would have been to determine the energy-temperature curve of each steel and then set the temperature for an arbitrary energy value. The aging effect would then amount to the increase in temperature required to obtain the arbitrary value of energy after exposure."

I would also like to remind Mr. Manuel that it is quite general for the chromium steels to show brittle fracture in notched impact tests at room temperature. A good example is the 4 to 6% chromium tubing, fathered by E. S. Dixon of the Texas Co. Let me quote some of his remarks in Chapter 18 of "The Book of Stainless Steels":

"Tubes made of 4 to 6% chromium steel when operating hot (above 300° F.) are ductile and tough. The impact value for this steel when hot is excellent. . . Although tubes of this alloy are strong, ductile and tough when heated, a tendency to be brittle when cold developed eventually after operation. . . The precautions to be taken are to clean the tubes when the unit first comes off the line, or before the tubes have cooled to a minimum metal temperature of approximately 300° F. If the tubes have cooled below the minimum metal temperature, they should be reheated before starting the turbining or cleaning operation."

Certainly this very useful alloy would have been a complete failure had it not been discovered that the dangerous "embrittlement" did not exist above 300° F. I would venture the opinion that, even in the "embrittled" condition, any of the steels studied in our recent investigation would be perfectly ductile under a notch in bending if the test temperature were 300° F. or higher. Consequently a low Charpy value at 70° F. in this family of steels is not a serious problem except during fabrication of cold metal with abraded or scratched surfaces, notches or sharp corners. Most people therefore tend to "baby"

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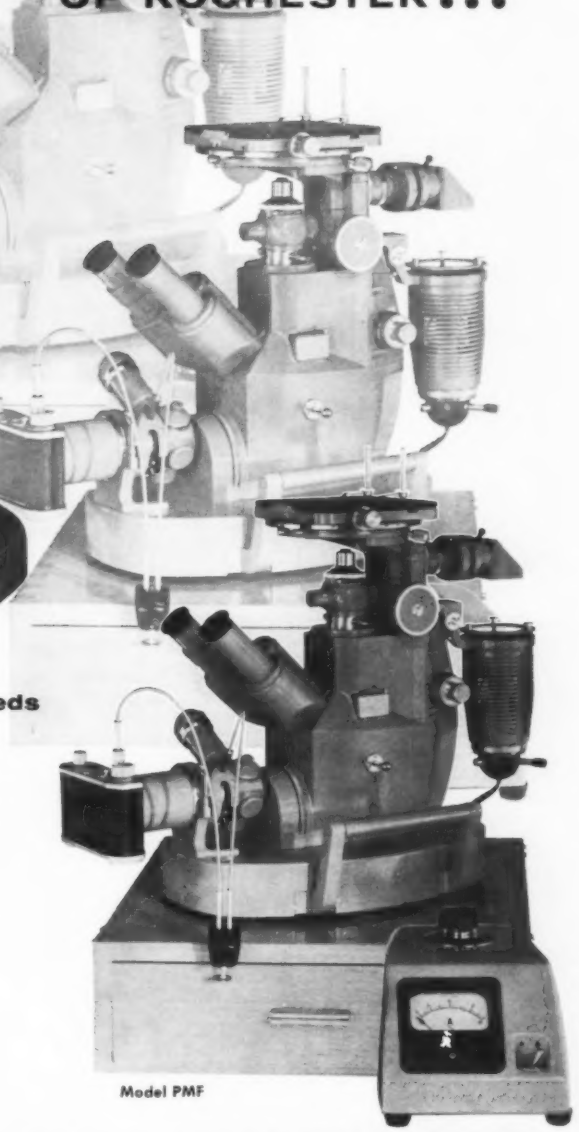

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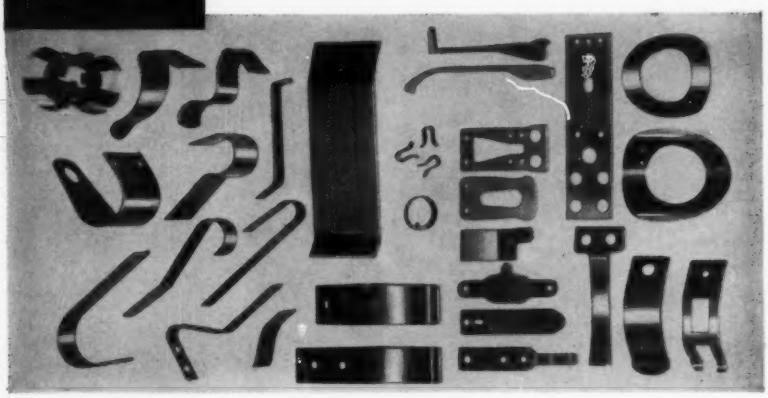

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Circle 1999 on Page 48-B

Correspondence . . .

high-chromium steels, and work them only when warm. I am quite sure any of the steels in our test can be welded successfully, even though strongly embrittled by a stay in the temperature range of 700 to 900° F., by the simple expedient of preheating the metal.

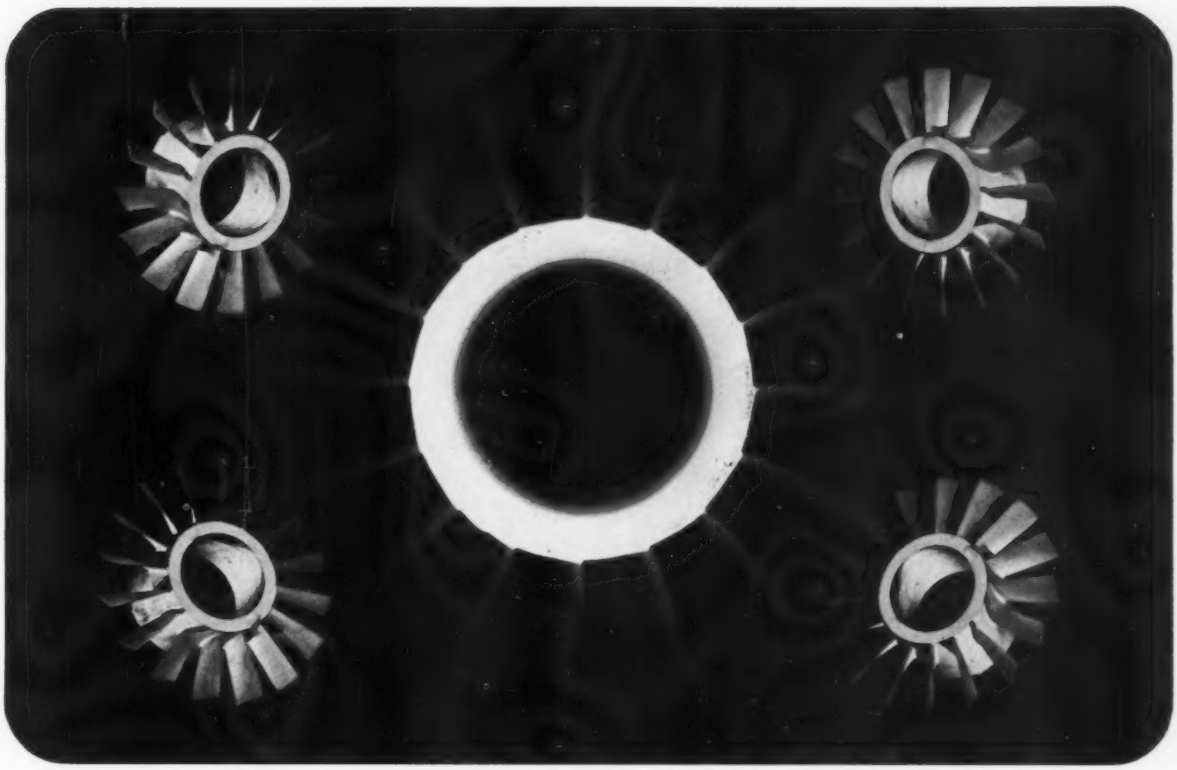
We must be realistic. Fabricators and users alike must live with these conditions. Knowing what to expect, it is a relatively simple matter to avoid trouble.

Lastly, Mr. Manuel asks for a specification for a nonembrittling Type 405 steel. We know what the desirable chromium is, but if you specify less than a 2% range, you pay a premium. Likewise, the paper indicates that molybdenum has a marked tendency toward reducing the tendency toward embrittlement in long service at 715 and 900° F. This addition also costs money. One purpose in publishing the paper was to give intending users enough information so they could decide which composition would satisfy the requirements for any particular applition. It might be a lot less expensive to handle the alloy at some safe temperature in the embrittled condition than to pay the cost for a special alloy with restricted range of elements. These are basic economics which the engineer must handle.

From personal experience I believe that it would be impossible to write a specification for any grade of steel which would satisfy every customer. This is probably the reason why in the alloy industry today we have so many variations in chemical analysis.

HOUSTON, TEX.

The appraisal of several high-chromium steels after many years' exposure in operating refinery equipment should clear away some of the doubts one still hears about the qualities of Type 405 stainless steel. As I see it, an outstanding factor in the materials given top ratings in the summaries is the beneficial effect of molybdenum. For example, 405 + Mo is rated "very good" for service at both 715° F. and 900° F; 410+Mo is rated "best" at 715° F. and "very good" at 900° F. "Sicromo" is rated "very good" at



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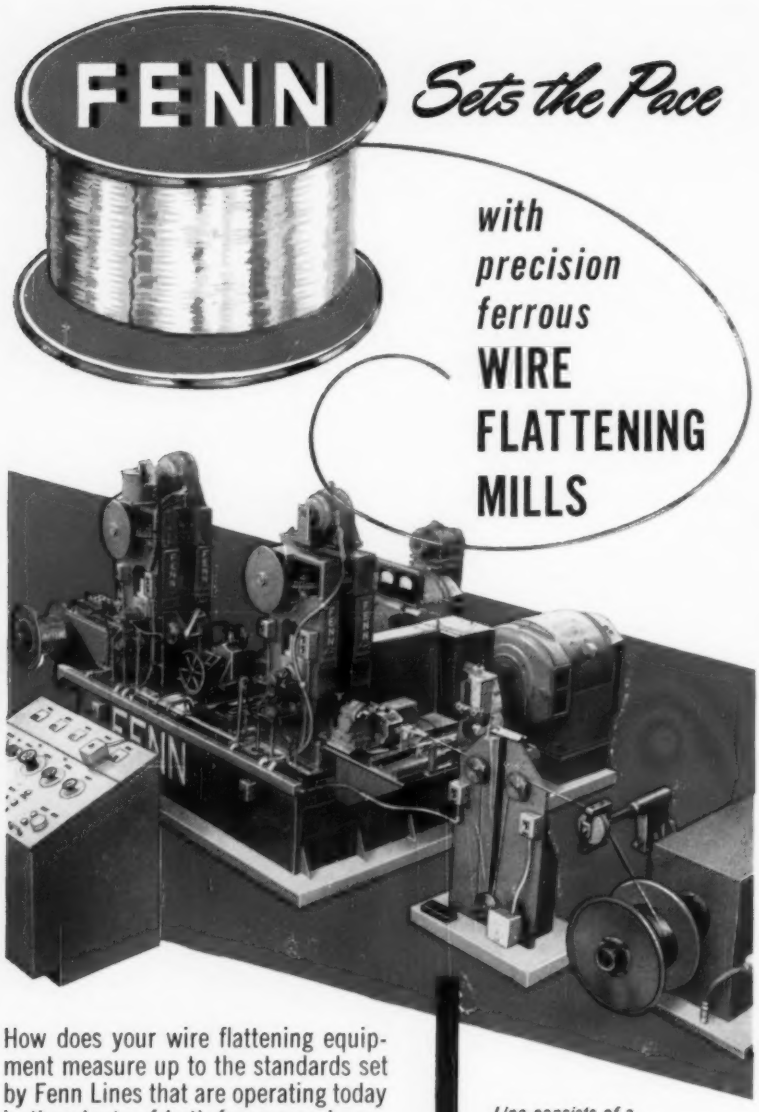

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Circle 2001 on Page 48-B

Correspondence . . .

715° F. and "good" at 900° F. Why, therefore, is not this modification used for all linings where 405 is specified? Is it that molybdenum introduces some problems in welding?

To the design engineer there appears to be little choice between the 410 + Mo and the 405 + Mo for best over-all results, except that he may get a little confused by the poor showing of the Code F steel, high in chromium and low in carbon, which was rated "poor" for the 715° F. exposure. (Incidentally, the straight Type 405, Code D, does not look very good either at that temperature.)

The unfortunate metallurgist has a more complicated job. He must juggle the chromium equivalent against prior treatments and stabilizing agents so as to keep the analysis inside of the gamma loop without being absolutely sure that it should be kept there. He would like to grain coarsen it to enhance its toughness but runs into fabricating trouble. That makes it a little rough!

F. K. Zerbe

Mr. Scheil's Reply – The only logical answer I can give to the question "Why is not 405 + Mo always used?" is that the cost is slightly more. I know that Standard Oil of California has used it for many lined coke drums, and I understand that one of the reasons for their preference for the chromium stainless steels with molybdenum added was that they had never found any 9 Cr, 1 Mo stainless steel which had embrittled in service. I cannot recall any difficulties we have had in welding or forming of Type 405 + Mo stainless steel. We did notice at one time that the grain was decidedly coarsened when the forming temperatures exceeded 2100° F. This, however, did not interfere with the nonhardening properties. We ran some tests of about 8000 hr. duration at the dangerous 885° temperature and could not detect any embrittling tendency in the grain coarsened condition.

Bayonne, N. J.

The data in Mr. Scheil's paper appear at first sight to show that the

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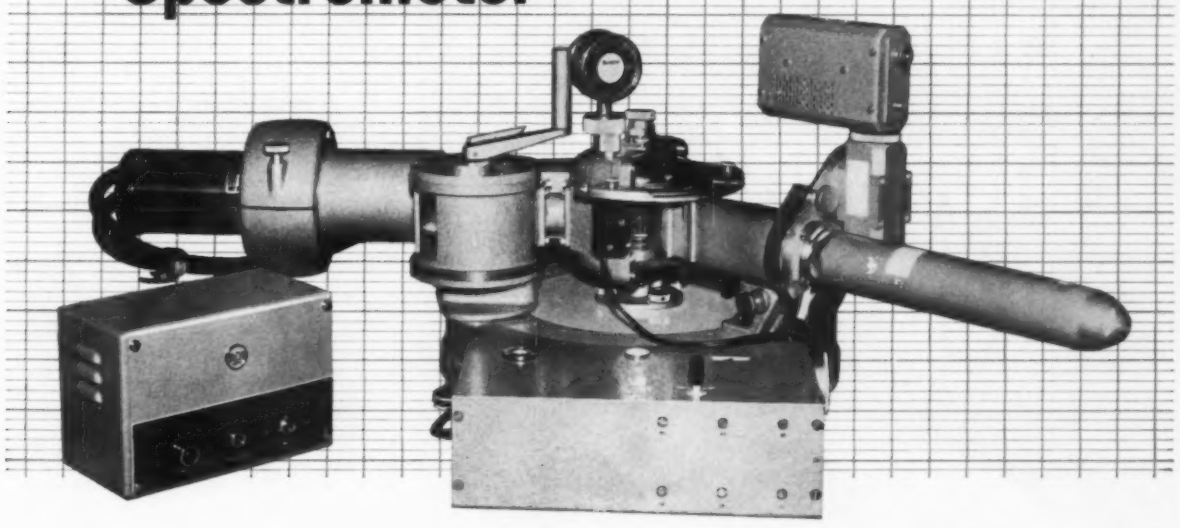

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Circle 2002 on Page 48-5

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Circle 2003 on Page 48-E

Correspondence . . .

steels containing 8 to 13% chromium do not suffer from "885° embrittlement". Upon studying the paper, however, I believe that it is playing a prominent role.

My interest dates back to some research done at U. S. Steel Corp.'s research laboratory and published in *Transactions* of the American Institute of Mining and Metallurgical Engineers in 1953 (Vol. 197, p. 690). A chromium-rich precipitate was found and identified with the embrittlement. The implication was clear, then, that the iron-chromium system was actually age hardening at temperatures lower than those necessary for sigma phase to form. Subsequent work at Carnegie Institute of Technology verified the mechanism and established a new "equilibrium" diagram (see Williams and Paxton, *Journal* of the Iron and Steel Institute, Vol. 185, 1957, p. 358). This paper suggests that a miscibility gap occurs in the system below 970° F. and, further, that the solubility of chromium in iron at 885° F. is about 10%.

I also understand that H. J. Blackburn of the metallurgy department of Cambridge University has recently secured electron photomicrographs showing early stages of precipitation in a 21% Cr steel after heating at 885° F. It may be that a similar study of the Code F steel (low-carbon 405 + Mo) would be most informative.

I suggest Code F steel because it shows very pronounced effects of aging at 715° F. Indeed its original Charpy impact (30 ft-lb. in annealed condition) has dropped to 2 ft-lb. after six years' exposure, while the original hardness, B-77, has increased to B-94. The data for the same steel exposed to 900° F. may perhaps show some sign of overaging during the interval between 21,000 to 74,000 hr., because the hardness slightly decreases and the Charpy value slightly increases in that interval.

Another possibility, I believe, should be borne in mind, and that is that the three heat treatments for Conditions I, II and III may have altered the amount and distribution of the carbides and nitrides in the steel – and possibly other elements

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Circle 2005 on Page 48-B

Correspondence . . .

in the matrix—and that this was further intensified by long exposure at high temperatures.

KENNETH G. CARROLL
Research Laboratory
International Nickel Co., Inc.

MR. SCHEIL'S REPLY—Mr. Carroll undoubtedly has made a good suggestion when he says that our samples might well be carefully studied under the electron microscope. Mr. Thielemann truly observed, in his letter to *Metal Progress*, June 1960, p. 138: "At 750° F., embrittlement can be due to several possible factors, and I believe that the predominant one is a disorder-to-order transformation which is retarded by such factors as cold work, impurities, and the diffusion rates of the alloying elements present. It follows that embrittlement has always been and still is a difficult phenomenon to pin down." Erection of barriers to the disorder-to-order transformation is very likely the reason we had best results with chromium steels after slight cold working.

Refractory Metals . . .

(Continued from p. 87)

(as little as 10% porosity will decrease strength by about 50%), this is a major problem in nonmetallic materials.

Oxides generally are quite stable in air at temperatures up to their melting points, but a few—magnesium oxide is one—volatilize at much lower temperatures. Some oxides are also susceptible to hydrolysis reactions with moist air. The disilicides resist oxidation in air because they form a plastic self-healing, protective film of silicon dioxide on the surface. However, molybdenum disilicide, the most attractive, is much less resistant to oxidation at intermediate temperatures (around 1650° F. or 900° C.) than at high temperatures. The volatility of their oxides makes refractory metals (particularly molybdenum and tungsten) very susceptible to oxidation in air at high temperatures. Promising approaches to the solution of this problem include (*a*) alloying to form complex oxides which are not vola-

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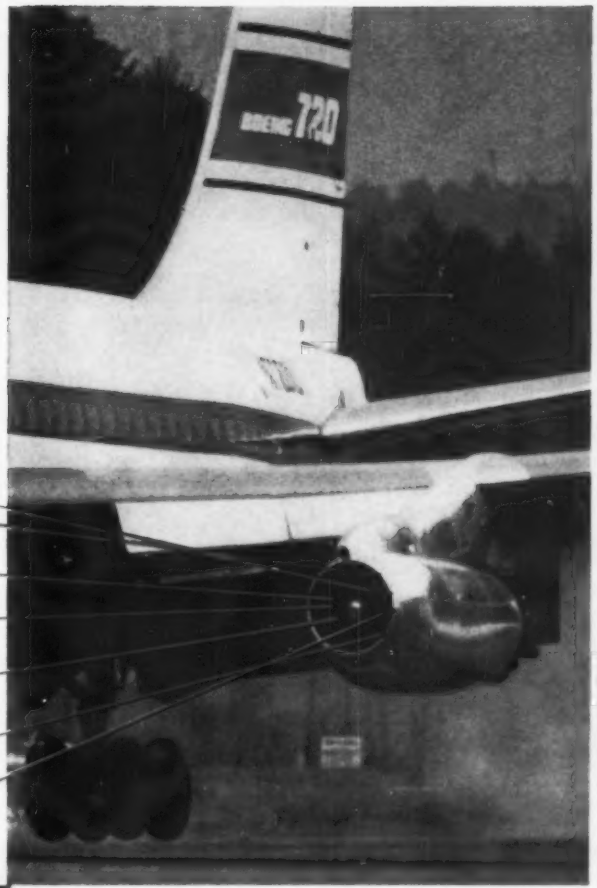

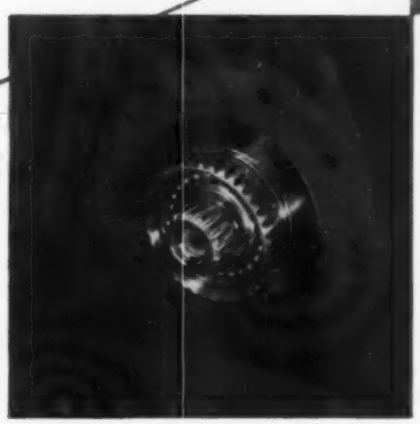

Thrust reverser bearing assemblies, made of Latrobe's Vac-Arc BG 41 Stainless, take compressive stresses of more than 600,000 psi and temperatures in excess of 800°F. as new Boeing 720 jetliner brakes to a stop. Bearings by Torrington Co.; Thrust Reversers by Rohr Aircraft; Jet Engines by Pratt & Whitney Aircraft.

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Circle 2006 on Page 48-B

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Circle 2007 on Page 48-B

Refractory Metals . . .

tile; (*b*) alloying to prevent cracking of scale by reducing its specific volume to more closely approximate that of the base metal; (*c*) alloying with elements whose oxides are thermodynamically more stable than that of the base metal; and (*d*) protective coating.

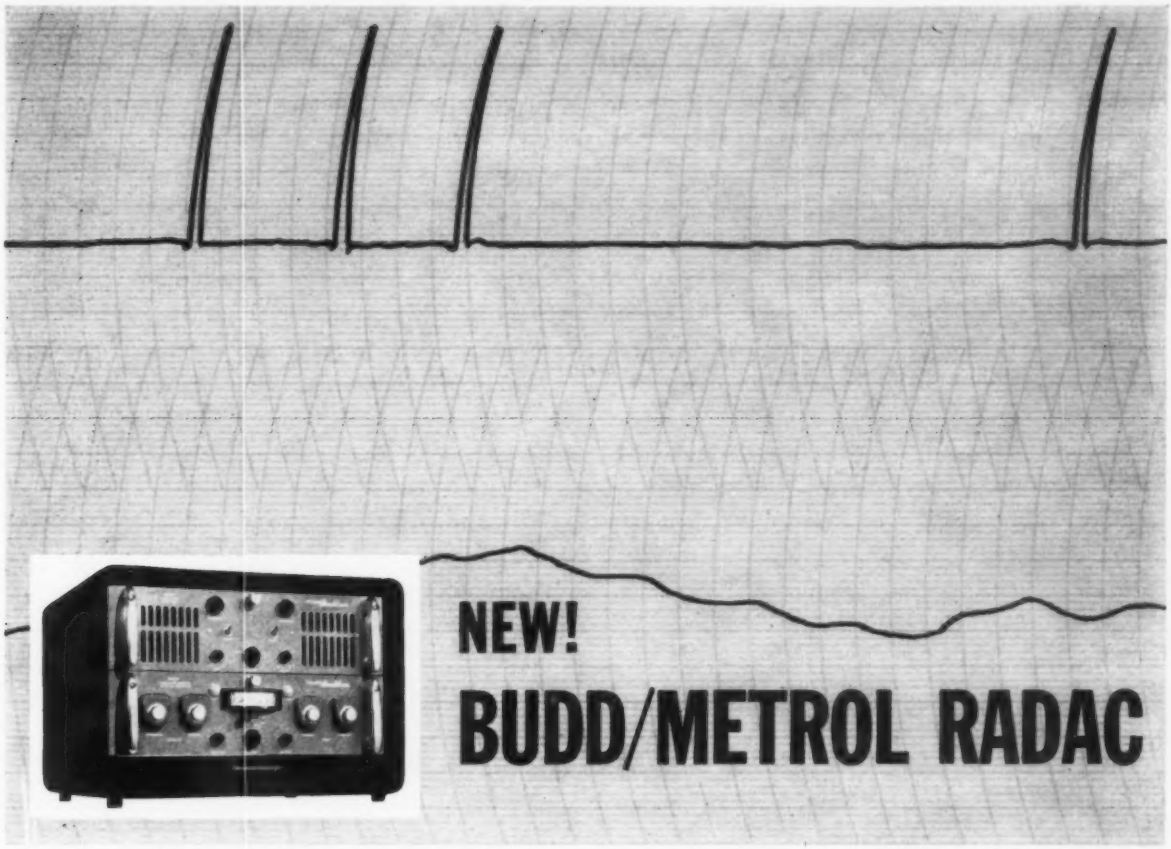
Compared with metals, nonmetals exhibit poor low-temperature ductility. Basically, most polycrystalline oxides, carbides, nitrides and the like remain brittle up to the melting point. The intermetallic compounds do exhibit some plasticity, but even the most ductile of these has about the same transition temperature as does the most brittle of the metals. Furthermore, advances in the technology of purification, grain refinement and hot-cold working procedures offer considerable hope for improvements in low-temperature ductility of the metals. Figure 6 (p. 86) shows how elastic modulus varies with temperature.

The resemblance between the elevated-temperature behavior of metals and nonmetals is remarkable. Both lose strength rapidly above homologous temperatures in the range of 0.35 to 0.60; this is caused by an analogous change in fracture characteristics from transcrystalline to intercrystalline. Properties which are structurally useful are generally maintained up to a homologous temperature of about 0.60.

Strength increases which seem to occur in nonmetals with increasing temperature are believed to be merely a manifestation of excessive notch sensitivity at the lower temperatures. (In other words, fracture occurs before the intrinsic strength of the material is reached.) The same phenomenon is observable in notched specimens of molybdenum. However, the strengths of metals below their recrystallization temperatures are much greater than those of nonmetals, and only above 4350° F. (2400° C.) does graphite show higher strength than metals.

Alloying Behavior

The refractory metals exhibit all varieties of alloying characteristics; their constitution diagrams vary from complete miscibility to no interaction at all. However, they seem to have one thing in common. None of them



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Circle 2008 on Page 48-B

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Circle 2009 on Page 48-B

Refractory Metals . . .

demonstrate allotropy – their crystal structures are stable at all temperatures. While this limits the possibilities of control of properties by heat treatment, it does offer one important advantage. When an optimum alloy with a desirable microstructure is developed, it is likely to be stable at all temperatures.

In designing optimum structural alloys, elementary solid-solution hardening is considered first. To begin, researchers study the rates at which various solute elements confer strength on the base metal, and also the attendant diminution of ductility. Then, more complex alloys containing optimum quantities of the two or three best individual solutes are analyzed. The results are almost always at least additive, and often there are other actions which are even more useful. By sacrificing some ductility, further increases in strength and resistance to softening during prolonged exposure to elevated temperatures are obtained by adding precipitation hardening (or more probably, dispersion hardening) agents.

One interesting example of a potentially important system was presented by D. W. Levinson (Armor Research Foundation) who discussed the titanium-tungsten phase diagram. According to him, about 21 at.% of tungsten could dissolve in body-centered cubic titanium, and about 25 at.% of titanium would be soluble in tungsten. By adding a small quantity of another element (such as carbon), an alloy could possibly be developed which would be strengthened at elevated temperature by the presence of a dispersion of carbides. Further, properties could be altered by heat treatments which would take advantage of the allotropy of titanium.

Protective Coatings Needed

Thus far, the rapid destruction of refractory metals by oxidizing atmospheres at elevated temperature has prevented them from taking their predestined place in the high-temperature materials field. One of the perversities of nature is that these metals cannot withstand contact with an air environment at temperatures where their other properties are most attractive. As a matter of fact, they

a name...
a company...
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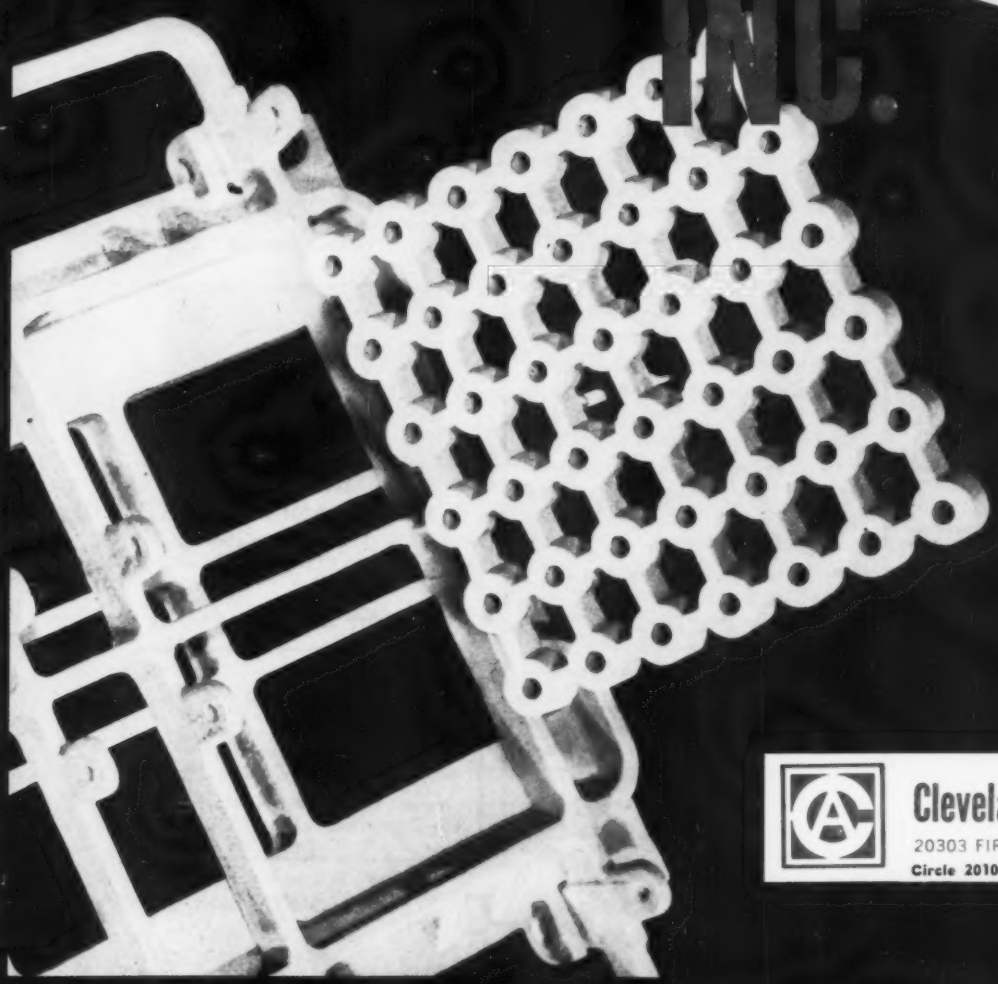

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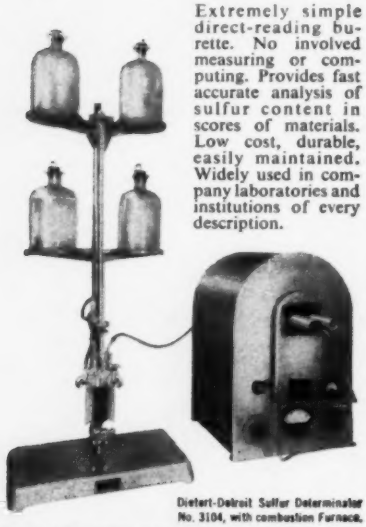

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Circle 2031 on Page 48-B

Refractory Metals . . .

are not only subject to gross surface oxidation, but are also embrittled by absorbed oxygen.

Alloys having improved oxidation resistance have not been developed, except at the sacrifice of other important properties such as strength, ductility, fabricability and weldability. Consequently, oxidation resistant coatings are also receiving much attention. Although research workers have recognized that coatings must be tailored and selected for their particular application, they have aimed at satisfying the following criteria:

1. Exclusion of oxygen from the metal surface.

2. Applicability to complex configurations by several processes (plating, cladding, vapor deposition, spraying and so forth).

3. High resistance to development of flaws, or capacity for self-healing of flaws, resulting from thermal cycling, thermal shock, impact, abrasion, deformation of base metal, or vibration.

4. Suitability for use on several alloys.

5. Negligible reduction in properties of base metals.

Oxidation resistant alloys which are sufficiently ductile to preclude flaws are being considered. For example, columbium or molybdenum may be coated with Inconel, or a columbium alloy containing a high percentage of titanium or zirconium might be used to protect a stronger columbium alloy. Another type of coating employs refractory intermetalic compounds such as molybdenum disilicide or silicon carbide. These are usually combined with a ductile or glassy material to add self-healing characteristics. Ceramics are also being investigated. Here again, a glass or ductile metal must usually be included to provide enough flow to heal defects. Some success has been achieved with aluminum oxide plus glass (to protect columbium) and aluminum oxide plus chromium (for coating molybdenum surfaces).

Recent coating development work at the Naval Research Laboratory (described by G. Sandoz) has indicated that zinc will effectively protect columbium and its alloys from oxidation between 1600 and 2000°

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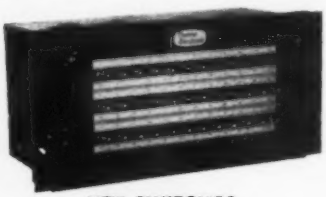

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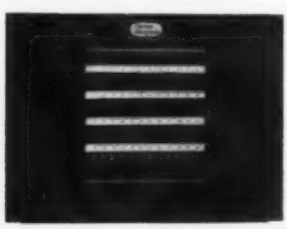

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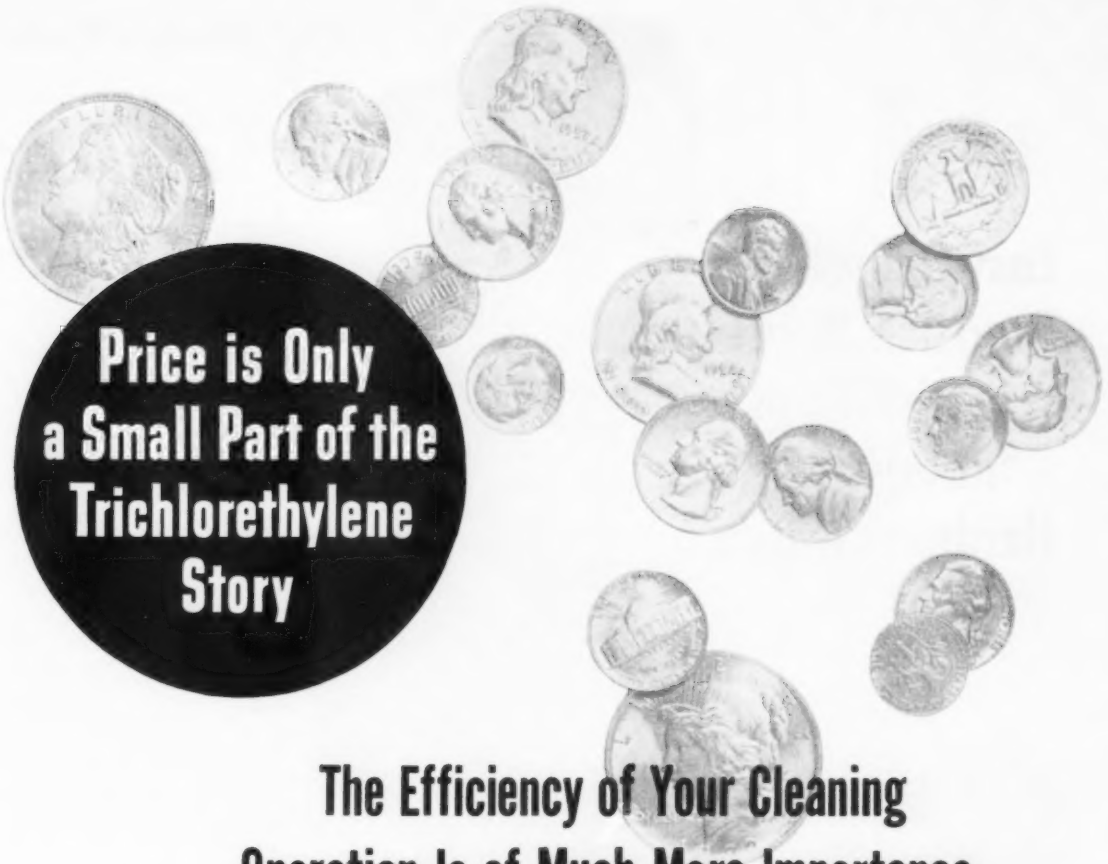
Circle 2011 on Page 48-B



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Circle 2013 on Page 48-B

Refractory Metals . . .

F. Actually, just as with any oxidation resistant coating or alloy, it is the oxide of zinc which affords the protection; its crystal structure makes it highly resistant to diffusion of oxygen. Coating adhesion along with additional oxidation resistance is assured by the formation of stable zinc-columbium intermetallic compounds at the interface. During exposure to elevated temperatures, zinc diffuses to the surface to replace the oxide lost by evaporation; this repairs any flaws which occur. The coating is easily applied and has a long life. However, it has disadvantages. Temperature is limited to 2000° F., the zinc evaporates or deteriorates rapidly in vacuum or neutral atmosphere, and the coating is suitable only for columbium and columbium alloys.

Testing Above 2000° F.

Considerable effort and ingenuity are demanded in solving the complex problems attendant on determining mechanical properties of refractory metals in the temperature range where they are most useful. Often, special equipment must be devised. As one example, G. K. Manning described a device used at Battelle Memorial Institute for testing in vacuum at 4000° F. Temperature variations of less than 20° F. over a 2-in. gage length have been made possible through use of half-cylindrical heating elements wound with 0.005-in. molybdenum ribbon plus an optical pyrometer temperature control through an extended Vycor-covered port. The vacuum in the hot chamber (which is 2½ in. in diameter by 8 in. long) is maintained by three oil diffusion pumps backed up by two mechanical pumps. Loads applied through screws are measured by a cooled SR-4 load cell at the bottom of the chamber; cell output is either read or recorded. An extensometer (to measure strain) consists of two molybdenum wires whose change in position is read, or recorded by high-speed movies, through a telemicroscope (a microscope with a very long working distance).

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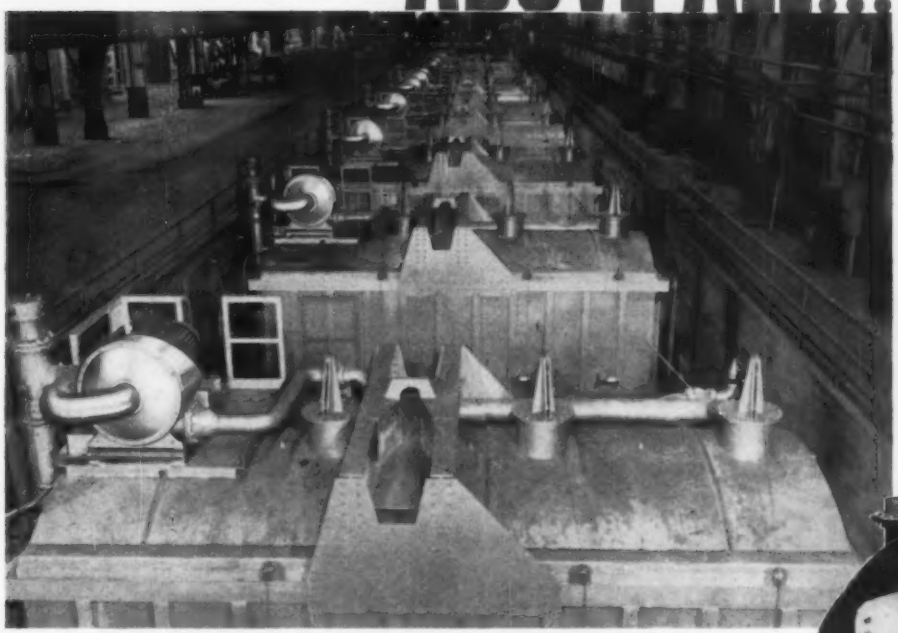

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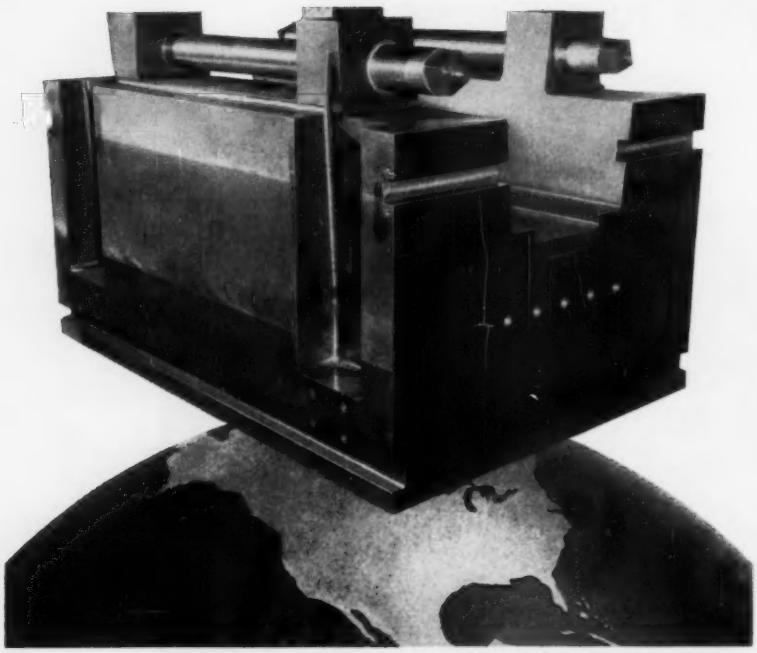

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Circle 2015 on Page 48-B

Refractory Metals . . .

up to 2300° F., and platinum-platinum, 13% rhodium is used from 2300 to 3200° F. According to E. C. Bernett, they have found this to be the most satisfactory method for rapid heating rates. Hydraulic loading through an electrohydraulic servo valve is controlled by a load cell of the differential transformer type. A 2-in. gage length extensometer is used and the outputs from it and the load cell are recorded. Strain rate capability from 0.00001 to 0.1 in. per in. per sec. has shown that tensile strength can be increased up to 800% by changing from the lower to the higher strain rate. The strength of N-155 at 2100° F., for example, was found to be 2000 psi. at 0.00001 in. per in. per sec., 6000 psi. at 0.001, 11,000 psi. at 0.01 and 16,000 psi. at 0.1 in. per in. per sec.

Convair has also found that thermocouples provide the most satisfactory temperature measurement and control for rapid heating rates. For duplicating service conditions in missiles, they have developed equipment with automatic programing accessories whose resistance heaters have a capability of 500° F. per sec. Strain rates ranging from dead stop to 0.1 in. per in. per sec. are controlled through a linear variable-transformer type extensometer.

Ceramics . . .

(Continued from p. 92)

conventional rotating beam fatigue test to study the fatigue behavior of Al_2O_3 at the elevated temperatures. Appropriate cylindrical fatigue specimens are employed along with a specially designed furnace for temperature control. Such factors as the influence of the test environment in relation to the mechanism of fatigue-crack formation are being evaluated. A notable result of these tests is the conclusion that the endurance limit of Al_2O_3 at 900° C. (1650° F.) is not significantly lower than it is at room temperature.

Cermets Also Receiving Attention

In addition to ceramics, considerable attention is being devoted to cermets of various types. Some of the more promising cermets are hot pressed titanium carbide bonded

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Circle 2016 on Page 48-E

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Milwaukee Malleable & Grey Iron Works, Milwaukee 46

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Circle 2017 on Page 48-B

Ceramics . . .

with molybdenum-nickel alloy, and aluminum oxide bonded with chromium. A new technique for producing cermets by infiltration has been described. In this instance, a porous oxide, such as compacted but unfired Al_2O_3, is impregnated with an aqueous solution of cupric salts; the salts are then converted to cupric oxide by heating. Finally, the porous compact is impregnated with molten silver to produce a product containing up to 50% silver. (Cupric oxide has been found essential if the silver is to penetrate properly.) Such infiltration cermets show substantially greater strength than cermets of the same composition produced by conventional methods.

Many cermet and powder metallurgy products are also being produced by slip-casting techniques. This method, a traditional process for fabricating ceramics, permits formation of intricate shapes that would be virtually impossible to produce by pressing.

Another innovation in cermet research has been the development of a cermet body that is relatively tough at ordinary temperatures, and is also strong at 1000 to 1100° C. (1830 to 2010° F.). This development is based on the general concept that a relatively large volume of metal can be interspersed with a hard and thermally stable ceramic, the structure of which is arranged in such a manner as to achieve optimum properties. Key to this development is the production of a lamellar arrangement of the two phases. In experimental studies, sheets of chromium-nickel alloy are interleaved and pressed with titanium carbide in varying thicknesses and proportions. Thicknesses on the order of 10 to 30 mils, and metal contents on the order of 40 to 60% have been studied. After firing this product at 1340° C. (2450° F.), impact values of 25 to 30 ft-lb. and tensile strengths above 40,000 psi. are obtainable at room temperature.

Reinforced Ceramics

A final example of the application of the composite material concept is in the development of metal-reinforced ceramic coatings. In this instance, a macroscale composite is produced with the metallic reinforcing component in the form of an expanded metal or mesh framework (which is similar to ordinary metal lath). This mesh is coated or plastered with various ceramic compositions. Reinforcing metals, ranging from mild steel through austenitic stainless to tantalum and molybdenum, have been studied. The more promising ceramic coatings consist of refractory oxides such as Al_2O_3 or ZrO_2 compounded into a porous cement-like product with such bonding agents as magnesium oxychloride or aluminum phosphate. Best results have been obtained by applying the ceramic coating as a stucco or plaster to the metallic reinforcement. These composite coatings are recommended for such applications as combustion chamber walls of ramjet engines and rockets. In repeated cycle short-term tests, typical coatings have been able to withstand as many as 12 to 15 5-min. cycles of heating to 2200° C. (4000° F.) for 20 to 30 sec. followed by a cooling period.

Significance of the Meeting

In summary, it should be acknowledged that this conference on mechanical properties of ceramics was highly significant in several respects. In almost every paper the speaker admittedly reached the limit of his knowledge of the subject. This clearly indicated the lack of complete knowledge, and the urgent need for a great deal more research into the fundamental structure and construction of solids. From the metallurgical viewpoint, it is of interest to note that widely known and well-established metallurgical tools and techniques are now being successfully applied to the solution of ceramic problems. Furthermore, many so-called metallurgical properties and behavior phenomena are now being observed and evaluated in nonmetallic materials.

Findings of this nature have already gone a long way toward destroying any hypothetical boundaries that may have existed between the science of metals and the science of ceramics. It becomes increasingly apparent that the truly significant contributions will be those that lead to a better basic understanding of all materials, whether they be classified as metallic, nonmetallic or combinations of both.

Liquid flow through a cross section of a Malleable differential carrier.

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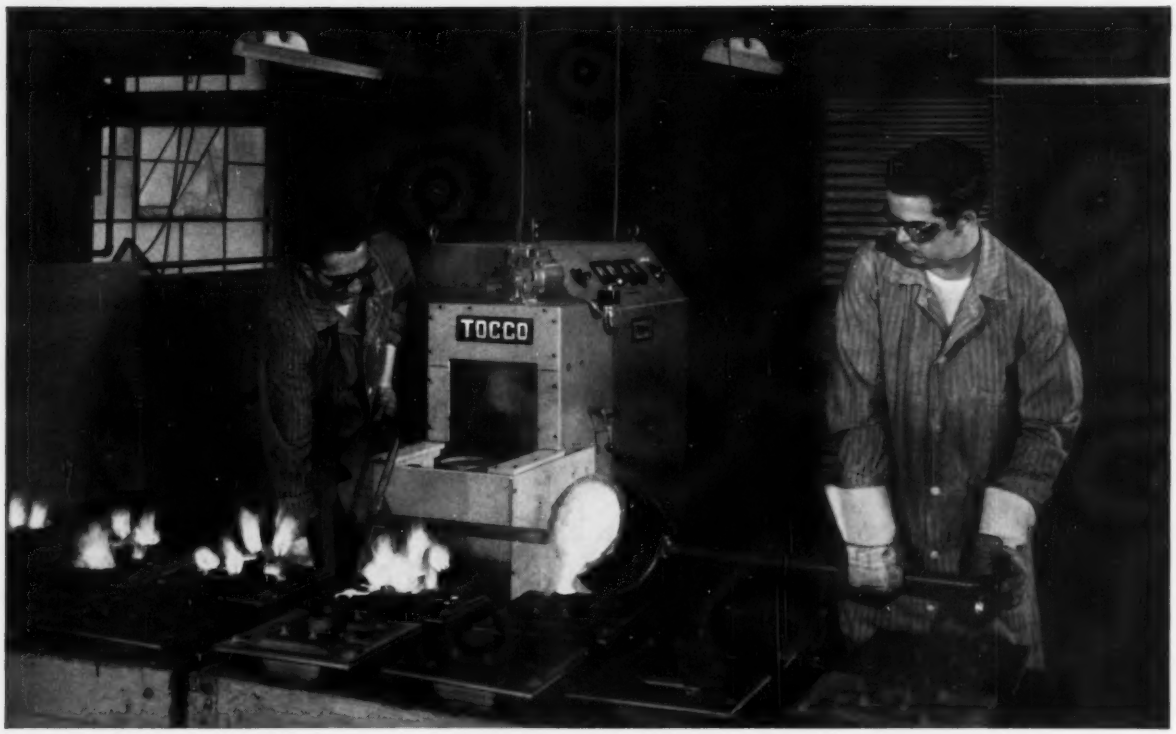

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melts bronze, aluminum and stainless steel for high-precision, porous-free castings

Morse Instrument Company, Hudson, Ohio, manufacturer of marine hardware and control instruments, recently switched from conventional furnaces to TOCCO Induction Melting. Results: greater speed, better working conditions and, above all, purer, sounder castings.

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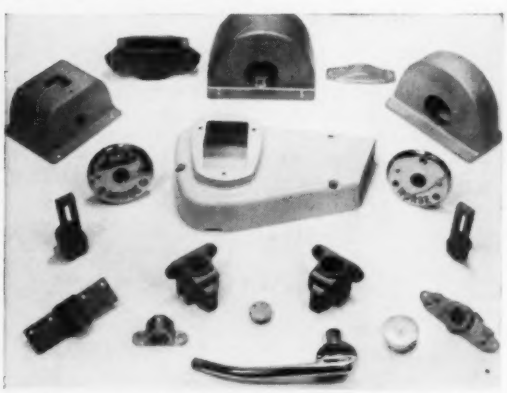

Sample castings produced by Morse Instrument Company with new shell molding process and TOCCO Induction Melting.

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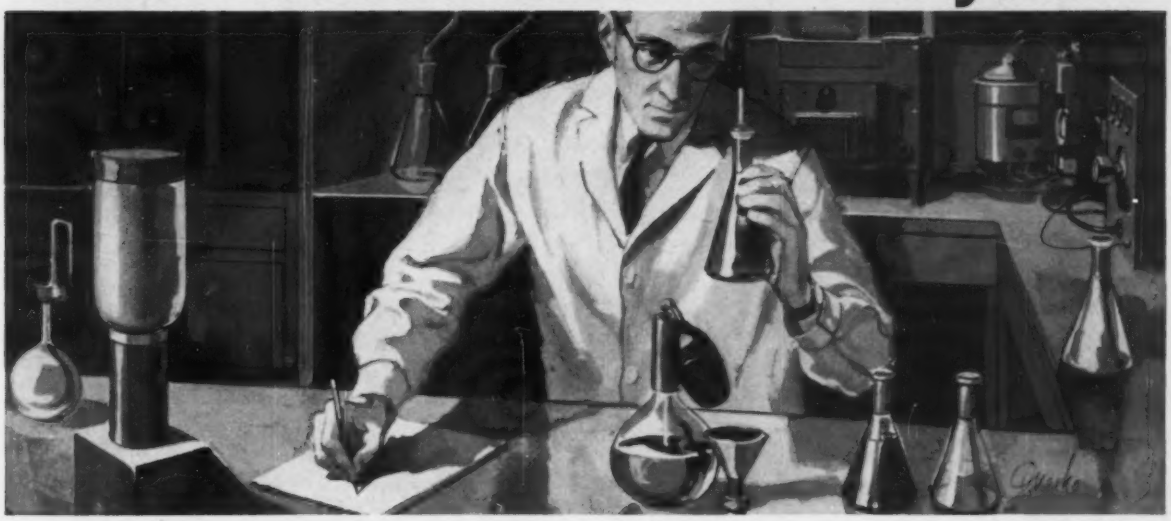
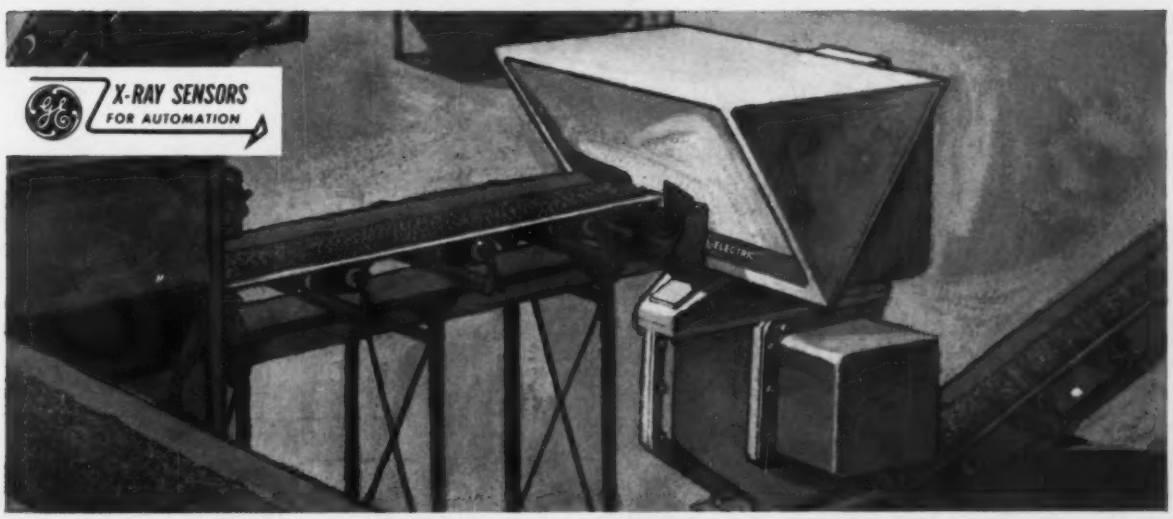


out of the lab...



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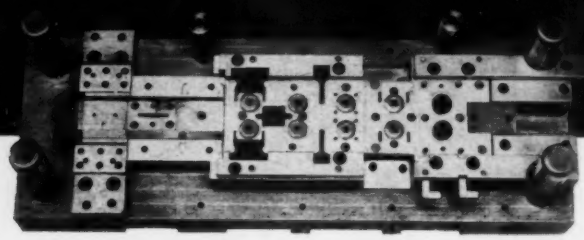
GENERAL ELECTRIC

Circle 2019 on Page 48-B



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This Type A-2 air-hardening tool and die steel is especially suited for applications in which the sections are very large... and those involving extreme accuracy of size and extreme hazards in hardening. Easy to machine... with excellent non-deforming properties ... Carpenter No. 484-FM provides fast, simple, safe handling at every step. It is also made by the exclusive MEL-TROL® Process to assure order-after-order uniformity. Use this MATCHED SET of Air-Hardening Tool and Die Steels—Vega-FM (Type A-6), No. 484-FM (Type A-2) and No. 610-FM (Type D-2)—for proper selection and predictable performance. Call your Carpenter SERVICE-CENTER for prompt delivery.

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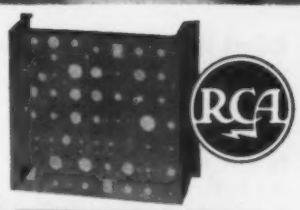
Iridite, in combination with other Allied Research processes, can provide a wide variety of finishes. As an example, Iridite 8-P applied to zinc or cadmium, followed by an application of Irilac, gives a highly attractive simulated brass finish.

GENERAL ELECTRIC COMPANY



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Circle 2021 on Page 48-B

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PERSONAL MENTION

JULIUS J. HARWOOD, ⓜ, new manager of the metallurgy department of Ford Motor Co.'s Scientific Laboratory, is now directing fundamental research programs on the physics of metals and alloy systems, physical metallurgy and ceramic science. Formerly head of the metallurgy branch of the Office of Naval Research in Washington, D.C., he joined ONR at its inception in 1946 and helped establish policies and practices for support by the Federal government of basic research in university, nonprofit and industrial research laboratories. He also coordinated all naval research programs in metallurgy and materials science. Before leaving Washington, he completed a four-month special assignment with the Advanced Research Projects Agency of the Department of Defense. In August of this year he was awarded the Navy's Meritorious Civilian Service Award in recognition of his efforts in the Navy research program.

His technical affiliations include A.S.M. – he is a member of the A.S.M. Seminar Committee and coordinator of the 1960 Seminar on Strengthening Mechanisms in Solids. He also edited the A.S.M. book "The Metal Molybdenum." Other technical activities include membership on the Executive Committee of the Institute of Metals Div. of A.I.M.E. and chairmanship of the Division's Refractory Metals Technical Committee.

Julius J. Harwood

Robert H. Gassner

ROBERT H. GASSNER, new consulting editor on the *Metal Progress* staff, is already familiar to our readers as an author – he reported the A.I.M.E. Southwest Metals and Minerals Conference in the September issue and this month covers the Southern California Regional Conference (p. 80). Chief metallurgist for Douglas Aircraft Co.'s El Segundo (Calif.) Div., he has worked on metallurgical problems associated with such famous Douglas aircraft as the AD Skyraider, and the A4D Skyhawk. A bomber pilot during World War II, he returned to his studies after the war; he received his bachelor of science degree from Queens College in 1947 and soon joined Douglas. He is well-known to ASMembers not only as a *Metal Progress* author but as a hard working Society member in both local and national activities. He was program chairman of the 1959 Western Metal Congress, general chairman of the 1960 Southern California Refractory Metals Conference and is currently assistant secretary of the Los Angeles Chapter ⓜ. A member of three Handbook committees and the technical council, he is also serving on the *Metal Progress* Advisory Committee.

Model 500-40 VS
(500 amp rated output)

For jobs where only the best will do—

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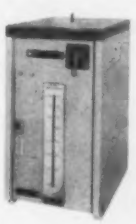
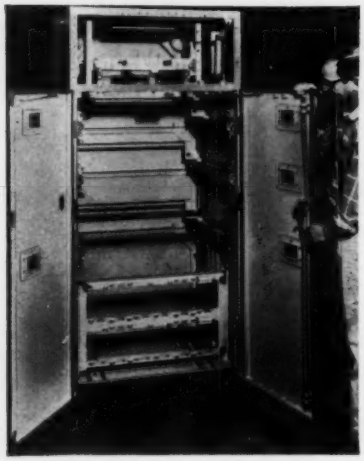


3

Circle 2022 on Page 48-B

Example . . .



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Circle 2023 on Page 48-B

Personals . . .

Joel R. Greenspan – received his bachelor of metallurgical engineering degree in June from Fenn College, Cleveland, and is now employed by Curtiss-Wright Corp., Woodridge, N. J., as senior metallurgical engineer.

R. P. Abendroth – now research scientist in the metallurgy section, general research division, Owens-Illinois Glass Co., Toledo, Ohio.

A. P. G. McGinnis – now manager, new products, development division, with Beryllium Corp.

Marvin L. Parrish – transferred from the Aviation Gas Turbine Div. of Westinghouse Electric Corp., Kansas City, Mo., to the Bettis Atomic Power Laboratory, Pittsburgh, materials department, materials engineering subdivision.

Herbert E. Knechtel – now in the metallography department of the Edgar C. Bain Laboratory for Fundamental Research of U. S. Steel Corp., Monroeville, Pa.

W. F. Alderson – from supervisor of field inspection and material certification for the South Albuquerque Works of ACF Industries to vice-president of the Mektrol Laboratories Inc., Alta Loma, Calif.

Edward F. Byars – now head of the mechanics department of West Virginia University.

J. M. Minore – currently vice-president and general manager of North American Refractories Ltd.

Alan W. Postlethwaite – from section head, materials process engineering to engineering manager, germanium transistor operation, Semiconductor Div., Raytheon Mfg. Co., Newton, Mass.

Robert M. Palmer – from manager of eastern district sales office in New Jersey for Hevi-Duty Electric Co., Milwaukee, Wis., to field sales manager.

Leroy Gilbert – working in the systems requirements section of the Martin Co., Denver division as senior specification engineer, preparing model specifications and interface documents for Titan ICBM's.

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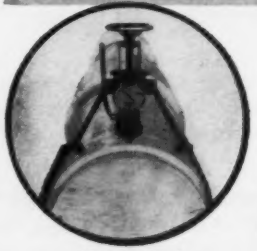

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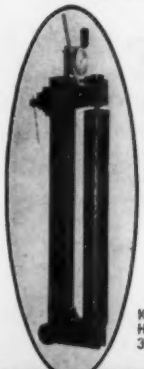

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Circle 2024 on Page 48-B

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Circle 2026 on Page 48-B

Personals . . .

Earl F. Adkins – now metallurgical engineer at the University of California Lawrence Radiation Laboratory in Livermore, Calif.

David L. Eaton – now supervisor of the research, development and production laboratory of General Instrument Corp.'s Thermoelectric Div.

Lawrence K. Hyde – currently manager of the testing machine division of Widermann Machine Co., King of Prussia, Pa.

Kermit A. Skeie – from western region manager in Los Angeles, Magnaflux Corp., Chicago, to the Chicago office in charge of commercial inspection.

Richard W. Fountain – appointed manager of metals research, technology department, Union Carbide Metals Co., Niagara Falls, N.Y.

David C. Goldberg – from manager of the metallurgy division, Westinghouse Aviation Gas Turbine Div., to the Westinghouse Astronuclear Laboratory, Pittsburgh.

Bayrd B. Berger – from metallurgist, Bethlehem Steel Co., to metallurgist, Bliss & Laughlin, Detroit.

Frank L. Wright – from staff engineer to chief engineer, Hoover Ball Div., Hoover Ball and Bearing Co., Middletown, Ohio.

Robert G. Strother – from eastern region manager, New York, for Magnaflux Corp., Chicago, to the Chicago office where he is in charge of field engineering.

Dale J. Richards – from assistant sales manager, Beryllium Corp., Reading, Pa., to manager, beryllium alloy sales, alloy division.

Robert R. Freeman – now civilian markets manager for refractory metals for Climax Molybdenum Co., a division of American Metal Climax Inc., New York.

John A. Richter – now design specialist, Martin Co., Orlando, Fla.

Ethan A. Smith, Jr. – from manager, development engineering, in the nuclear division of the Beryllium Corp., Hazleton, Pa., to manager, beryllium metal sales.

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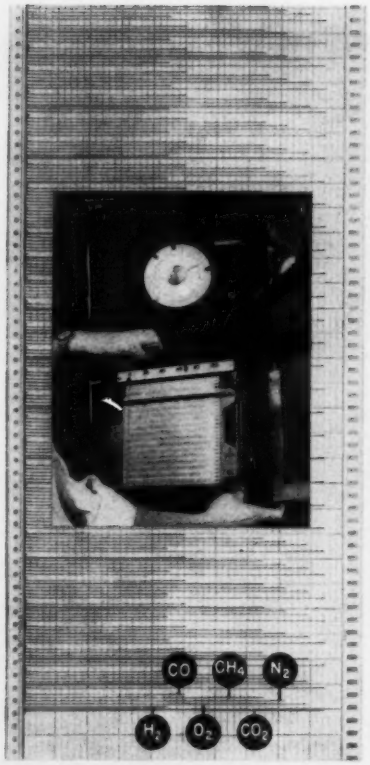

Chart record shows 6 components of furnace atmosphere measured cyclically by Furnace Gas Analyzer (inset).

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The new Perkin-Elmer Furnace Atmosphere Analyzer lets you analyze furnace atmospheres with all the accuracy, speed and completeness needed for precise control of heat-treat furnaces, gas generators, kilns or other combustion devices.

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INSTRUMENT DIVISION
Perkin-Elmer
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Circle 2028 on Page 48-B

Personals . . .

Robert F. Lutz – from chief metallurgist and heat treat superintendent, Rockwell-Standard, Newark, Ohio, to factory manager, Bosworth Steel Treating Corp., Detroit.

William A. Klawitter – from metallurgist to supervisor, magnetic and expansion alloys research, Carpenter Steel Co., Reading, Pa.

H. Earl Love – from Philadelphia sales office Pyrometer Co. of America, Penndel, Pa., to assistant sales manager, eastern division.

James W. Faber – metallurgical engineer, from Westinghouse Aviation Gas Turbine Div., Kansas City, Mo., to metallurgical engineer, Westinghouse Atomic Power Laboratory, Pittsburgh.

R. E. Bockrath – transferred to the technical department in the home office of Dow Metal Products Co., division of Dow Chemical Co., in Midland, Mich.

Walter H. Braun – from supervisor of quality control, Stainless & Strip Div., Jones & Laughlin Steel Corp., Detroit.

George Jagaciak – now senior engineer with Olin Mathieson Co., New Haven, Conn.

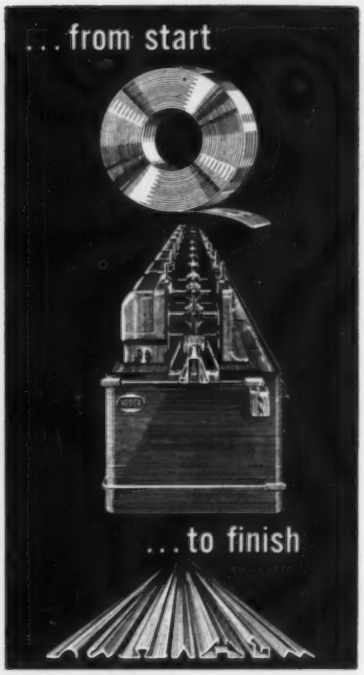
William H. Thomas—from general superintendent of the Coke and Iron Div., Pittsburgh Coke & Chemical Co., Pittsburgh, to technical assistant to the vice-president of the division.

Charles D. Brown – from manager of marketing for the light military electronics department, General Electric Co., Utica, N. Y. to manager, marketing, at G.E.'s instrument department in West Lynn, Mass.

Eugene A. March – from assistant works manager at Crucible Steel Co. of America's Midland, Pa., plant, to director of metallurgy for the company.

H. H. Mullen, manager of the resistance welding department, Ampco Metal Inc., Milwaukee, Wis. – elected president of the Resistance Welding Alloy Assoc.

Boyd Cass, – now general manager, metals–refractories, for Howe Sound Co., New York.



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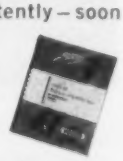

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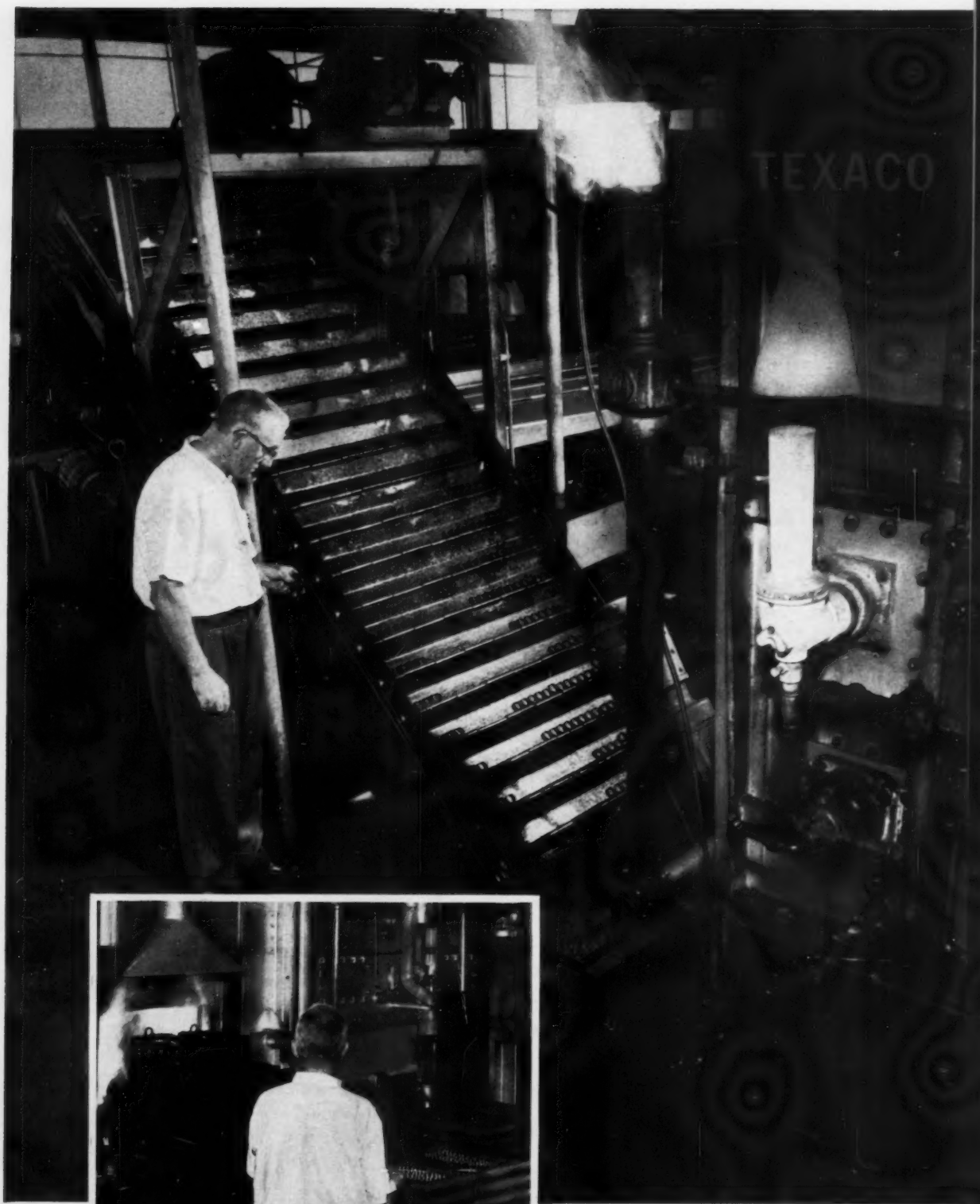

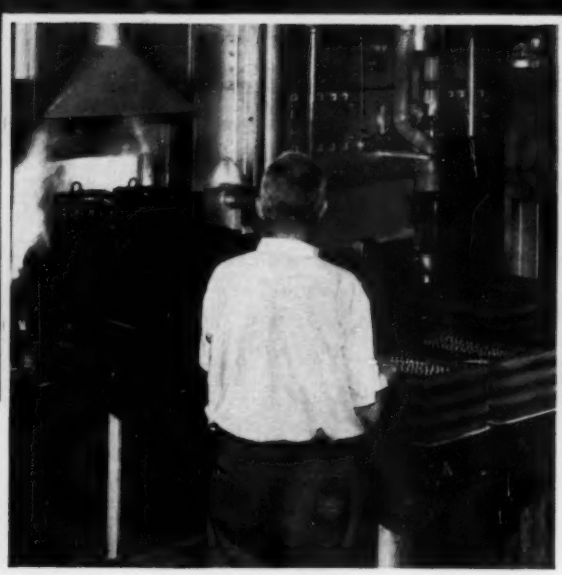

Photos taken at Hoover Ball and Bearing Company, Ann Arbor, Mich., show (left) parts going into heat treat furnace and (above) coming out of Quenchtex bath.

QUENCHTEX OILS GIVE UNIFORM HARDENING IN THE PIECE

with improved grain structure... no darkening of metal...longer bath life...

The proper choice of a quenching oil depends on the analysis of the steel being used and the hardness desired, among other factors.

A properly chosen quench for any given steel should remove heat fast in the high temperature range, and at a lower rate as the temperature drops through the low ranges where the metal becomes brittle and subject to stress. Because steels vary widely in analysis, Texaco offers three separate QUENCHTEX OILS—each with a different cooling curve.

The differences in cooling rate between the three QUENCHTEX OILS are functions of their composition:

- **QUENCHTEX 500**—a conventional or straight mineral oil of low viscosity;
- **QUENCHTEX 510**—a medium-speed oil blended with special additives;
- **QUENCHTEX 520**—a high-speed oil blended from refined paraffin base crudes plus additives.

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- Stability at recommended temperatures
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- **Compatibility with other quenching oils. You can begin using Quenchtex now—regardless of the oil now in your tanks.**

A Texaco Metalworking Specialist will be glad to take a sample of the oil you are now using for testing by Texaco's Research Laboratory. A cooling curve will be run on the sample and the compatible QUENCHTEX OIL will be recommended for make-up. For further information contact the nearest of the more than 2,300 Texaco Distributing Plants or write:

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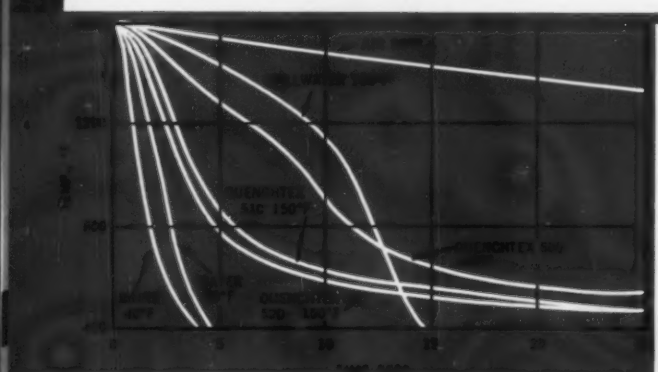

Chart shows cooling rates of several quenching media including QUENCHTEX 500, 510 and 520.

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For products where full hardness combined with minimum distortion is required—gears, ball and roller bearings, bearing races, etc.—hot oil quenching with MARQUENCH can help reduce the number of rejects, increase product load capacities, and in some cases permit closer tolerances before quenching.

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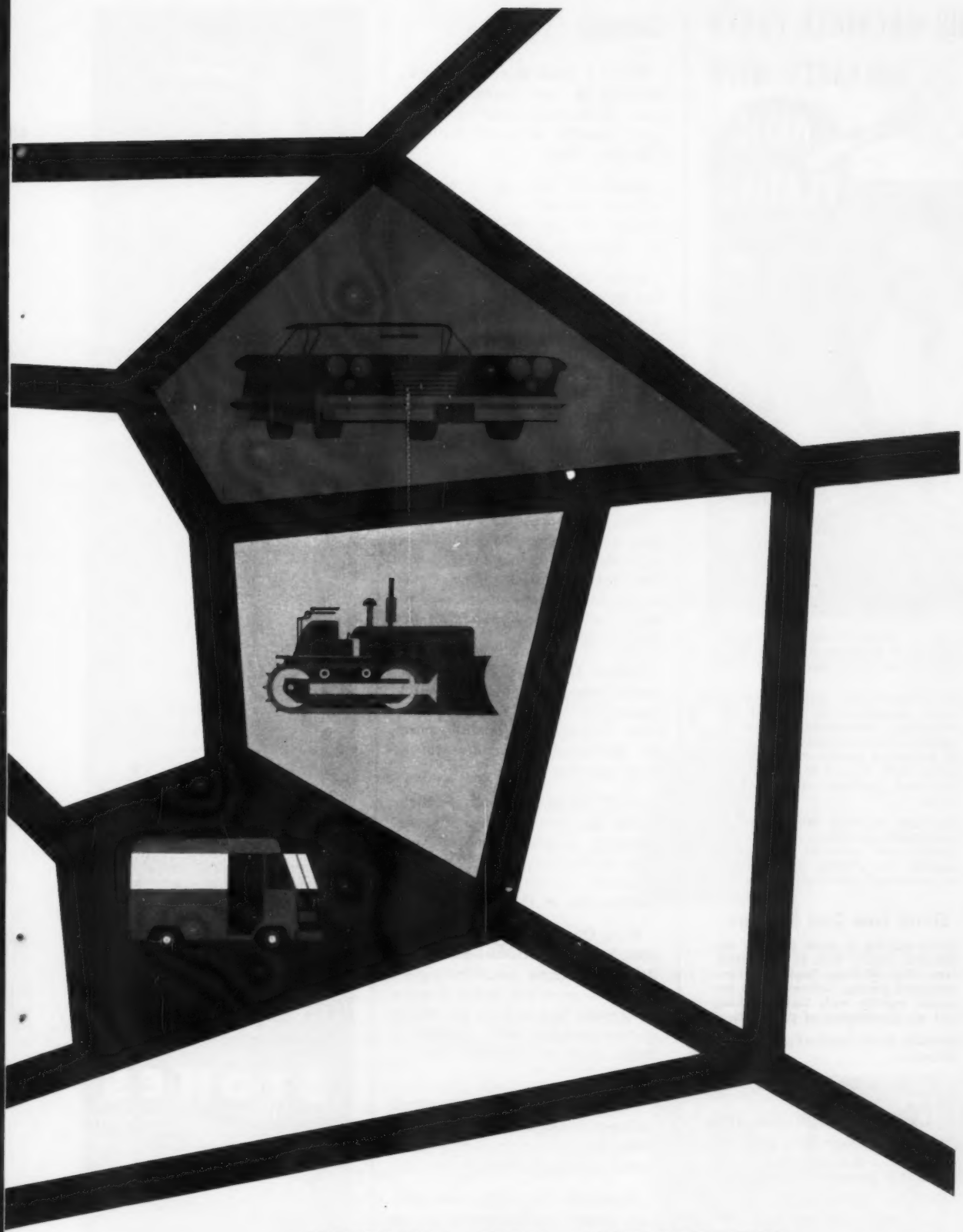

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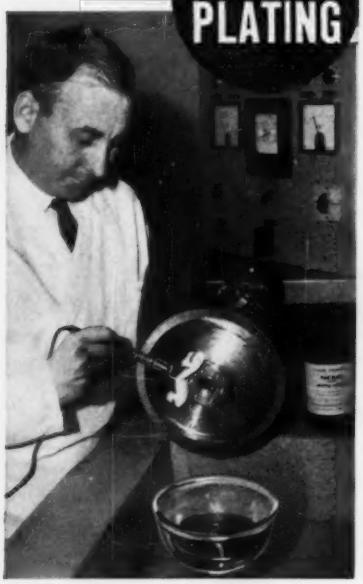

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Ceramics . . .

Robert I. Jaffee and **George K. Manning** — now technical managers in the department of metallurgy, Battelle Memorial Institute, Columbus, Ohio.

Royden S. Pratt — from staff technical director to technical and research director, Bridgeport Brass Co., Bridgeport, Conn.

Julian Glasser and **William E. Few** — formerly associated as consultants in chemical and metallurgical fields in Chattanooga, Tenn., now president and vice-president, respectively, in a new corporation, Chemical and Metallurgical Research Inc., Chattanooga.

J. A. Bauscher — now vice-president in charge of research, Lee Wilson Engineering Co., Cleveland.

Max Rae Ahrens — from resident physical metallurgist, Climax Molybdenum Co., division of American Metal Climax, in Climax, Colo., to assistant manager of abrasion resistant alloy development in the Denver office.

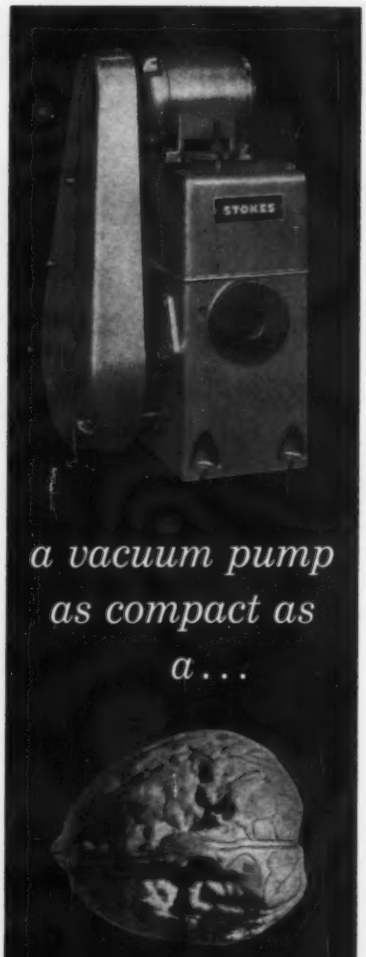
Robert D. Wylie — from assistant manager of quality control, Babcock & Wilcox Co., Barberton, Ohio, to manager of quality control for the manufacturing department, boiler division.

F. E. Werner and **L. S. Richardson** — now manager and supervising engineer, respectively, alloy studies section, metallurgy department, Westinghouse Research Laboratories in Pittsburgh.

R. A. Quadt — from vice-president, research and development, for Bridgeport Brass Co., Bridgeport, Conn., to president and a director of Reactive Metals, Inc.; he remains a vice-president with Bridgeport Brass, which will manage Reactive Metals.

Gerald R. Garinger — from assistant branch manager in Toledo, Ohio, for Carpenter Steel Co., to branch manager in Indianapolis, Ind.

Patrick D. Diggs — now salesman in the southeastern states for Riverside-Alloy Metal Div., H. K. Porter Co. Inc., working out of the division's southern office in Atlanta.



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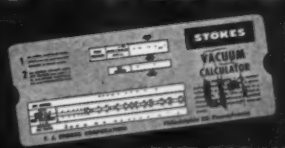

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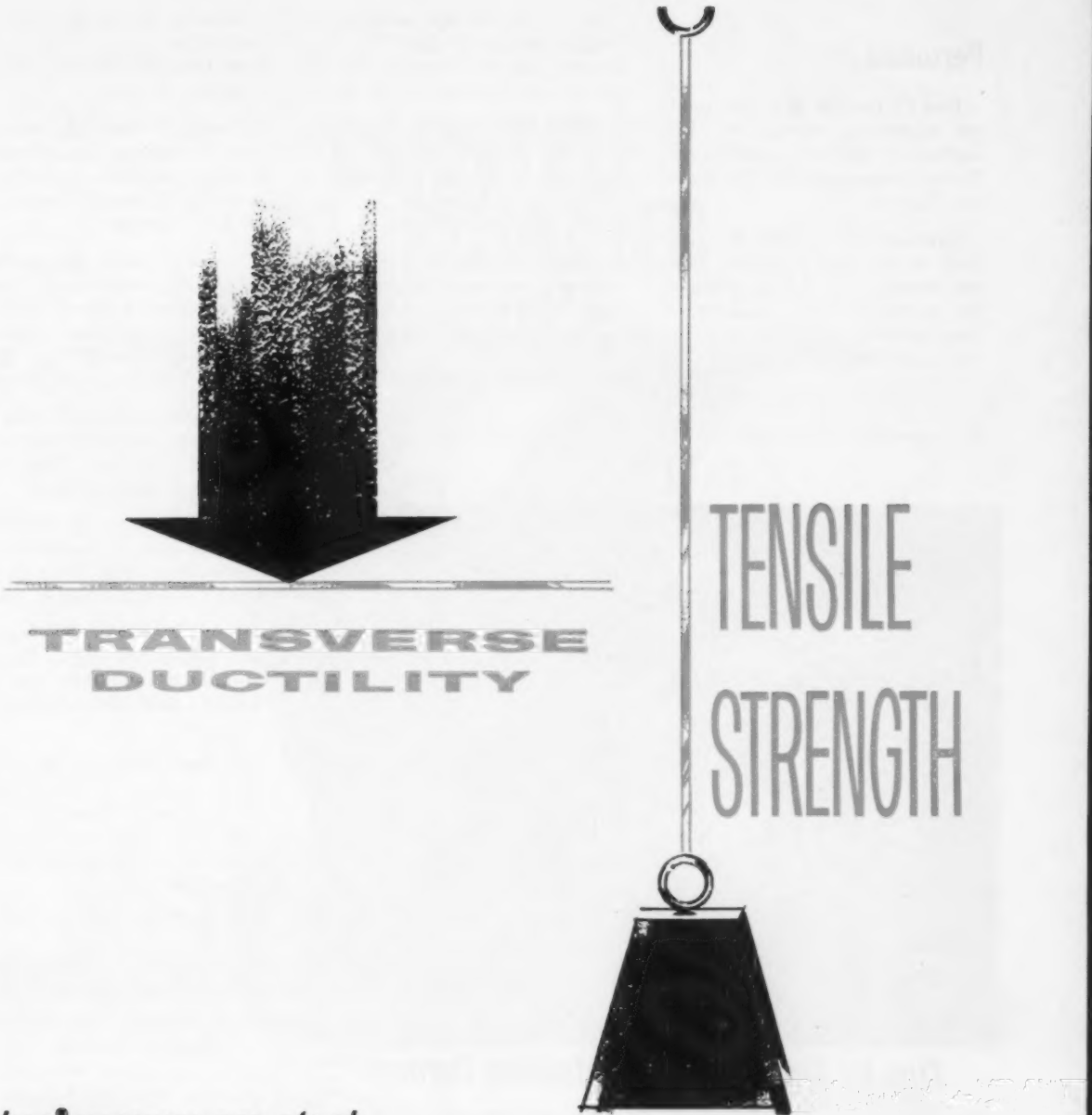

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Timken consumable electrode vacuum arc steel is available in ingots up to 24" in diameter, weighing up to 10,000 lbs. and in the form of bars and seamless tubing in a wide range of alloy and stainless steel analyses. Our metallurgists are ready to work with you to provide the steels you need in developing stronger, lighter parts. Call or write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

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Fine Alloy **STEEL**

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Personals . . .

Paul C. Cornish – from product engineering manager to chief engineer, product development, Weston Instruments Div., Daystrom, Inc., Newark, N. J.

Lawrence L. Garber – from head of the battery division, Electric Autolite Co., Toledo, Ohio, to the president's staff, working on manufacturing, properties and capital equipment.

M. W. Saxman – resigned as president of Latrobe Steel Co. after 36 years with the company; he will continue as chairman of the board.

Walter J. Bissinger – now sales promotion engineer for gear tooth induction hardening equipment in the Gould and Eberhardt Div., Norton Co., Worcester, Mass.

Richard J. Rand – from head of the Cincinnati sales branch of Crucible Steel Co. of America, Pittsburgh, to manager of the Pittsburgh sales branch.

Clark K. Benson – from vice-president in charge of sales to president, Heat and Control, Inc., San Francisco.

Thomas S. Simms – now manager of materials and process, refrigeration engineering, for the Hotpoint Co., division of General Electric Co., Chicago.

Joseph F. Libsch – member of Lehigh University faculty for 14 years, named head of the department of metallurgical engineering, succeeding **Robert D. Stout**, now dean of Lehigh's Graduate School.

Kenneth J. Cave – now technical sales representative for the southern Ohio and West Virginia territory of Heatbath Corp.

James H. Bly – from head, technical sales, to director of science applications, High Voltage Engineering Corp., Burlington, Mass.

Denis P. Walsh – from midwest region manager, Chicago, to manager of distributor and representative sales for Magnaflux Corp., Chicago.

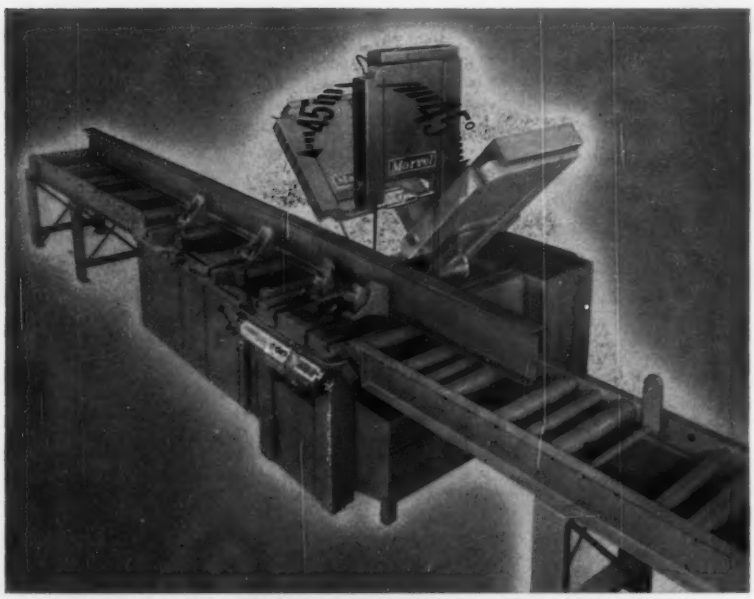
William Brenner, Jr. – from research engineer at the Youngstown, Ohio, plant of Jones & Laughlin Steel Corp.'s Stainless and Strip Div. to service metallurgist at the Louisville, Ohio, plant.

J. D. Hagans, sales manager, Ohio Steel Foundry Co., Springfield, Ohio – elected president of the Alloy Casting Institute, located in Garden City, N.Y.

William H. Myers – from plant metallurgist at the Wire Rope Div. plant of Jones & Laughlin Steel Corp. in Muncie, Ind., to metallurgical service engineer in J&L's technical services division, Pittsburgh.

Robert P. Bozzone – from supervising metallurgist of special metals, quality control, to assistant to the works manager, special assignments, for Allegheny Ludlum Steel Corp., Pittsburgh. He succeeds **Robert E. Christian** who has been named general superintendent at the Bagdad operation of the West Leechburg Works of Allegheny Ludlum.

Horace J. Grover – now staff physicist in the department of mechanical engineering, Battelle Memorial Institute.



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MARVEL No. 81 Series Band Saws are proving themselves daily, as the most versatile machine tools in production metalworking plants.

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MARVEL Metal Cutting SAWS

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Circle 2037 on Page 48-B

Personals . . .

Edward J. Skiba – now executive vice-president of Brown Aluminum & Chemical Co., a wholly owned subsidiary of Brown Fintube Co., Elyria, Ohio.

Lars Ekholm – from general sales manager, Climax Molybdenum Co., a division of American Metal Climax, to vice-president of eastern operations for the company.

Wesley H. Hauschildt – from plant metallurgist, light metals department, American Brake Shoe Co., to chief production engineer for aluminum operations in the foundry department of the Bay City, Mich., plant of Dow Metal Products Co., division of Dow Chemical Co.

David K. Stuart – from manager of the Chicago sales branch, Crucible Steel Co. of America, to staff assistant to the assistant general sales manager, field sales.

David Swan – from manager, planning, to vice-president, technology, Union Carbide Metals Co., a division of Union Carbide Corp., New York.

Wells E. Ellis – from assistant lubrication engineer to assistant chief engineer, physical laboratories, Timken Roller Bearing Co., Canton, Ohio.

Max E. Miles – now service engineer in the southwest sales district of Morse Twist Drill and Machine Co., New Bedford, Mass., assigned to the district office located in Dallas, Tex.

John S. Billingsley – retired as assistant to the vice-president, sales, Crucible Steel Co. of America, Pittsburgh, after 37 years.

Roy E. Blue, chief product engineer, Amplex Div., Chrysler Corp., Detroit – elected president of the American Powder Metallurgy Institute.

William G. Brown – from works manager to vice-president and sales manager, Seymour Mfg. Co., Seymour, Conn.

Karl A. Semlak – resigned from the pigments department of E. I. du Pont de Nemours & Co., Inc., to study medicine at the University of Pittsburgh.

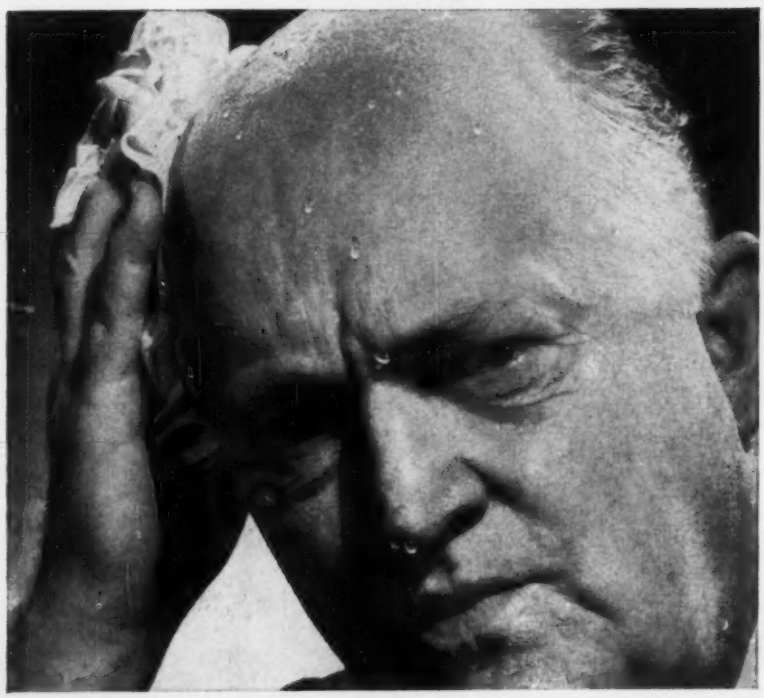
E. W. Kalb – now manager of market development, Vanadium-Alloys Steel Co., Latrobe, Pa.

John W. Keegan – from eastern sales manager, Herscott Corp., Rockford, Ill., to metallurgist, hot and cold heading steels, for Carpenter Steel Co., Reading, Pa.

Raymond Dhue, Jr. – moved from Dallas, Tex., to Louisville, Ky., to take over responsibility for sales in the latter area, reporting to the southern regional office of Parker Rust Proof Co. in St. Louis, Mo.

J. A. Cairns, vice-president of sales, Allied Research Products, Inc., has been elected to the Board of Trustees of the Metal Finishing Suppliers Association.

Charles A. Cardarelli – from assistant general sales manager in the general offices of Crucible Steel Co. of America, Pittsburgh, to assistant manager of the St. Louis branch.



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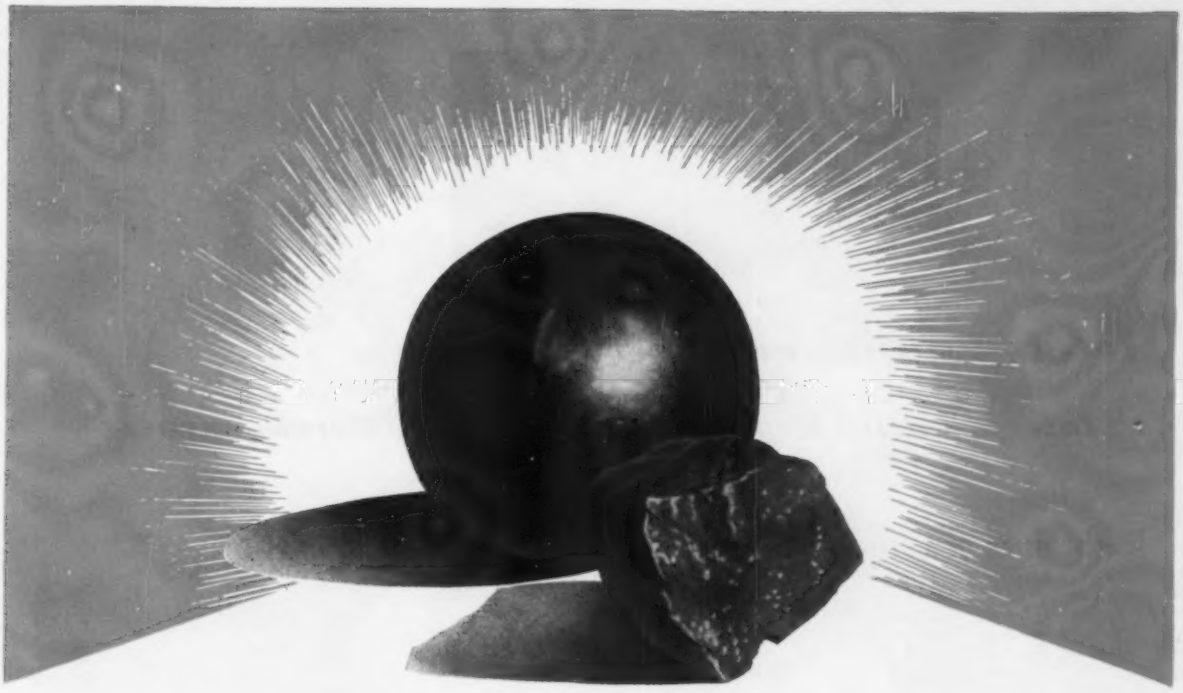

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Circle 2039 on Page 48-B

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Mechanisms of Corrosion

Digest of "Mechanisms of Corrosion", a Seminar sponsored by the Chicago-Western Chapter of the A.S.M., April 14, 1960, Argonne National Laboratory, Argonne, Ill. The highlights of the five talks are reviewed here.

"OXIDATION OF METALS" was the subject discussed by the first speaker, E. A. Gulbransen (Westinghouse Research Laboratories). Traditionally, oxidation of metals has been investigated by (*a*) observing the reaction products and deducing what is happening, and (*b*) measuring oxidation rates. The latter approach has been quite popular since Wagner presented his theory of oxidation, a mechanism based on the diffusion of metal or oxygen ions through interstitial sites or through cation and anion defects in the oxide film.

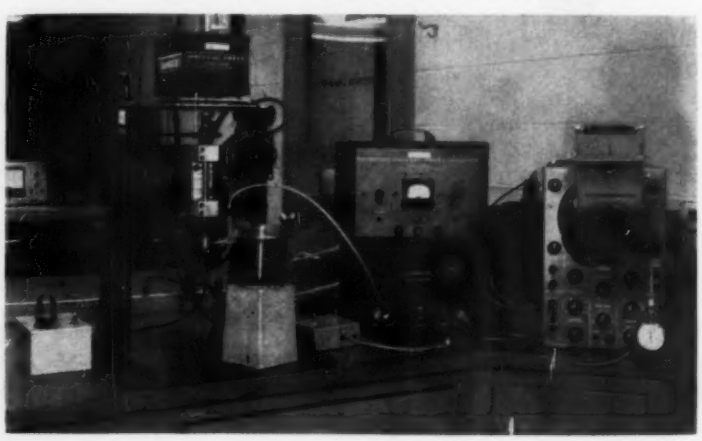
The electron optical microscope offers a most useful tool to observe events and enables researchers to correlate these observations with measurements. In oxidation and corrosion reactions, environment, impurities, metal structure and stress all are important. As an example, Dr. Gulbransen mentioned the Indian iron column which has withstood 1670 years without corroding because of the dry climate. (Corrosion rates can vary 100-fold, depending on the humidity.) It appears that normal oxidation takes place in dry zones while wet environments enhance electrochemical action. In the latter, local attack is the important parameter. However, in normal oxidation the oxide film and the reaction are assumed to be uniform, and the metal underlying the oxide is assumed to be structureless over a particular grain.

Recent developments have shown that crystal orientation, line and point defects determine the mechanical properties of the metal. These same factors may also determine the nature of the scaling reactions on metallic surfaces. The first evidence that the reaction product is not continuous was recently uncovered by Bardolle and Benard. Upon oxidizing Armco iron at relatively low oxygen pressures, they observed several oxide nuclei of definite crystal habit on any one single metal grain. Never was a single crystal of oxide observed to form on a single crystal of iron.

In a series of experiments conducted by Gulbransen and others, scaling reactions were carried out so

Fig. 1 – Blade-Shaped Platelets of Iron Oxide Formed on Pure Iron Reacted in 10% Steam, 90% Argon at 450° F. for 48 Hr. 10,000 ×

Fig. 2 – Area and Line Mapping Equipment With the Various Components. This equipment is used in observing local electrical action on a corroding surface



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The non-magnetic stainless steel parts above are used by Waterman Products Company, Philadelphia, Pa., in electron tubes. They are bright annealed at 1150 C (2102 F) maximum temperature in a dry hydrogen atmosphere on a 15 minute cycle. The furnace employs an Inconel muffle, water cooled at the rear for quick cooling of the work.

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Corrosion . . .

that the oxide formation could be followed directly in the electron microscope, and the reaction products could be identified while in position by electron diffraction techniques. Three types of localized crystal habits were observed. In dry oxygen, thin oxide whiskers, 150 A. in diameter and up to 20,000 A. high, formed on the surface of the annealed metal. Each whisker is a single crystal of αFe_2O_3. When the atmosphere is 10% steam, 90% argon, thin blade-shaped platelets form (see Fig. 1). They are αFe_2O_3, 100 to 8000 A. wide and 30,000 A. long. Water increases the reaction rate and effects the site and crystal habit of the reaction product. When cold worked iron or iron-containing interstitial impurities is reacted in dry oxygen, thin, rounded oxide platelets, 100 A. thick and 75,000 A. wide and high, form.

Gulbransen and others also investigated the role that (*a*) cold working, (*b*) external stress and (*c*) internal stresses due to a precipitate play on the crystal habit of the forming oxide. For instance, when specimens of stainless steel were exposed to wet oxygen (plus a trace of hydrochloric acid) at 600° C. (1110° F.) for 138 hr., the crystal habit of the oxide changed from platelets and whiskers to grown platelets as the applied stress was increased. Unstressed material displayed only whiskers.

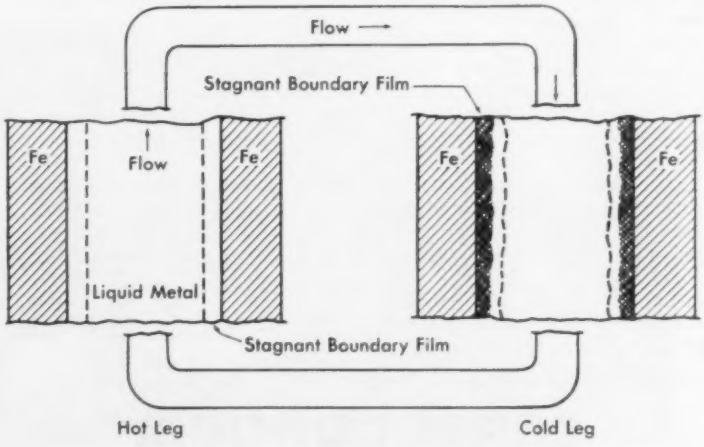
At present, it is not known whether the whiskers and the platelets grow out of the oxide or out of the metal. If they were growing out of the metal, they could actually be setting up trenching and possibly stress concentration sites by localized corrosion. Materials which exhibited stress-corrosion cracking showed platelets, while alloys, such as Inconel and Nichrome, which do not stress crack did not show platelets.

This technique, which affords a means to identify and observe the formation of the scaling products, when coupled with studies of kinetics, will undoubtedly shed some light on many unexplained scaling phenomena such as the sudden increase in scaling rate in such metals as zirconium and columbium.

Aqueous corrosion was covered by H. T. Francis (Armour Research Foundation), who began by stating that the electrochemical nature of aqueous corrosion has been well recognized for many years. However, in general it is thought that *gross* attack or direct corrosion is of a chemical nature, whereas localized attack is considered to be electrochemical.

A recent technique of his allows him to observe directly the local action taking place on a corroding metal surface. This technique, referred to as electrochemical mapping, can in turn be subdivided into two methods which complement each other: line scanning and area scanning. With the former technique, he can plot the instantaneous intensity of the anodic and cathodic areas along a line on the corroding

Fig. 3 – Schematic of Thermal Mass Transfer of Iron by a Liquid Metal. Iron is dissolved in the hot leg and is carried to the cold leg where it forms crystals which then deposit



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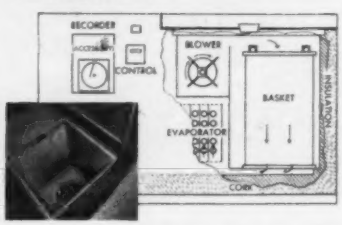

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Circle 2043 on Page 48-B

Corrosion . . .

surface. The latter method graphically maps, at any given time, the locations of these areas with some indication of their intensity.

Basically, this technique measures potential differences in the corrosive solution as a function of position along the corroding metal. In turn, these measured potentials indicate the galvanic current or electrolytic action at particular places.

The potential difference is measured with a reference electrode located quite close to a rotating cylinder of the material which is immersed in the solution in question. The resulting signals are recorded on an oscilloscope. A picture of the experimental setup is shown in Fig. 2. In line scanning, the reference electrode is kept stationary, and the variation in potential along a line on the circumference of the rotating cylinder is recorded on the oscilloscope. In area scanning, the reference probe moves up and down along the axis of the rotating cylinder to plot the relative cathodic and anodic areas while the variation in potential is presented on the scope as the z-axis modulation, or intensity.

That the specimen must be rotated is a limitation to this technique in that corrosion cannot be investigated under stagnant conditions.

The limit of resolving power is dictated by how close the probe can be located to the surface of the material. Thus, if this distance is small relative to the distance between the cathodic and anodic areas, the measured potentials are likely to show separate cathodic and anodic areas, and give a reasonable indication of current densities. The area and line scanning techniques reveal the presence of pits and their growth, among other things.

To demonstrate this technique, slides were shown illustrating that when a sample of steel was placed in a dilute solution of hydrochloric acid, rapidly shifting cathodic and anodic areas of varying intensities were formed on the surface of the steel. These results are particularly significant since corrosion of steel in dilute hydrochloric acid falls in the category of general attack or direct corrosion. On the other hand, when this steel was placed in a dilute solution of sodium chloride, a

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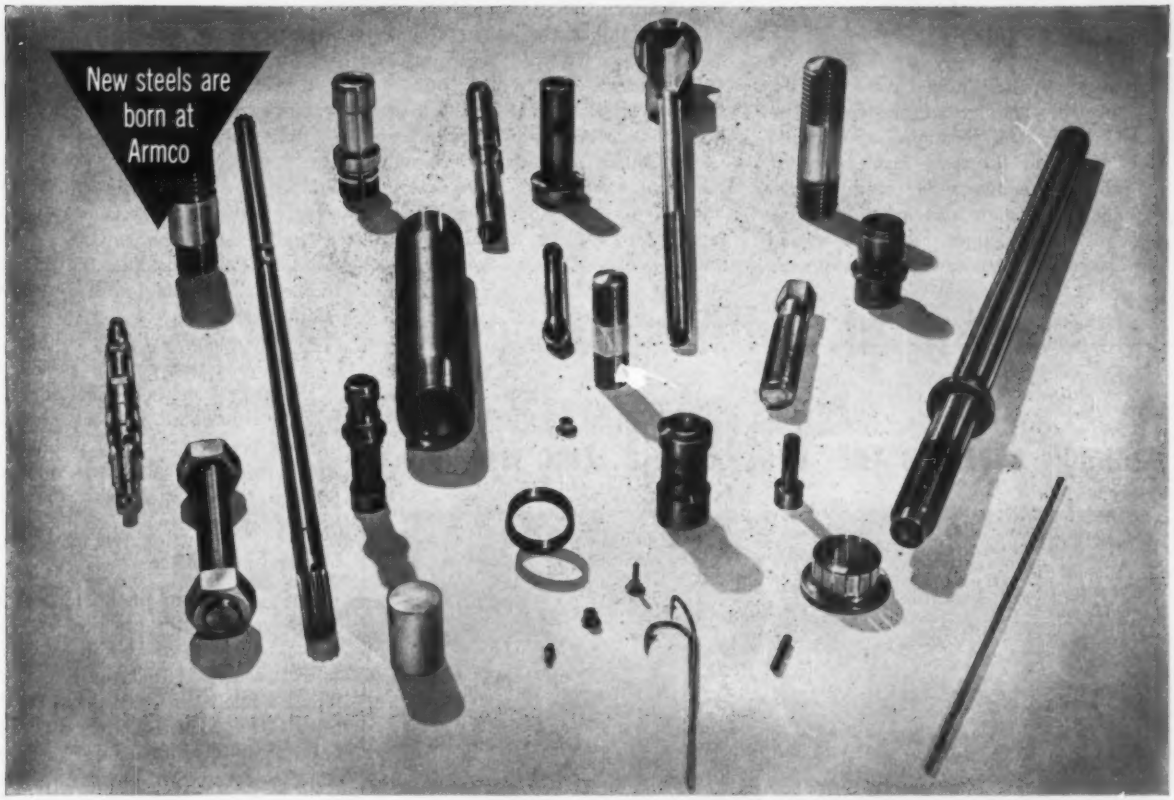

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more localized action was observed. Again, anodic areas, which are potential pit locations, appear and disappear. In some instances, they become progressively more anodic, and ultimately develop into active pits. Sometimes, cathodic action seems to stimulate subsequent anodic activity at the same locations.

Small inhibitor additions reduce or eliminate cathodic and anodic areas; this was clearly demonstrated when steel was immersed in a dilute sodium chloride solution to which small amounts of sodium chromate were added. Depending on the amount added, inhibitors rapidly decrease or eliminate such areas.

With this technique, the nature of stress-corrosion can also be investigated merely by stressing the specimen exposed to the corroding medium. As before, cathodic and anodic areas were observed, and cracks were found associated with anodic areas. However, it is not clear whether the cracks originated at the anodic area or the cracks made the area anodic. This most perplexing question still remains unanswered.

In summary, this technique clearly shows that general corrosion is definitely electrochemical in nature. Furthermore, it is a powerful tool for investigating any system in which there is local attack but the location of the area under attack is uncertain.

Mechanism of Attack

The mechanism of liquid metal attack was the subject of J. R. Weeks (Brookhaven National Laboratory). In introducing his talk, he said that liquid metals are excellent high-temperature coolants because of their low vapor pressure and excellent heat transfer coefficients. These properties make them useful in nuclear power reactors because of the very high heat fluxes available from a nuclear fuel. However, their use introduces a special type of corrosion phenomenon. In it there is a continuous dissolution of the container material into the liquid metal in the hottest portion of the heat exchanger (hot leg). This is accompanied by the continuous reprecipitation of the solute from solution in the cooler part of the heat exchanger (cold leg).

The process consists of the following stages: solution, diffusion, and bulk transport of the dissolved metal by the solution, followed by nucleation, transport, and growth and sintering of the crystallites in the cold leg (see Fig. 3). After going into solution, the metal diffuses through a relatively stagnant layer lying next to the walls of the hot leg. Application of kinetic equations to measured rates of solution indicate that this process is the rate controlling step in all simple systems. The nature of the liquid metal flow – whether it is turbulent or not – affects both diffusion and transport of the dissolved metal. Nucleation of the crystallites, which occurs at the cold leg, requires a high degree of supersaturation. As expected, nucleation is accelerated

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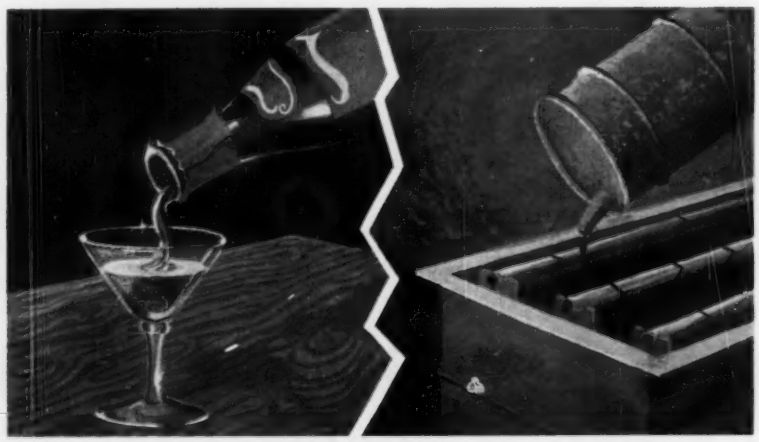

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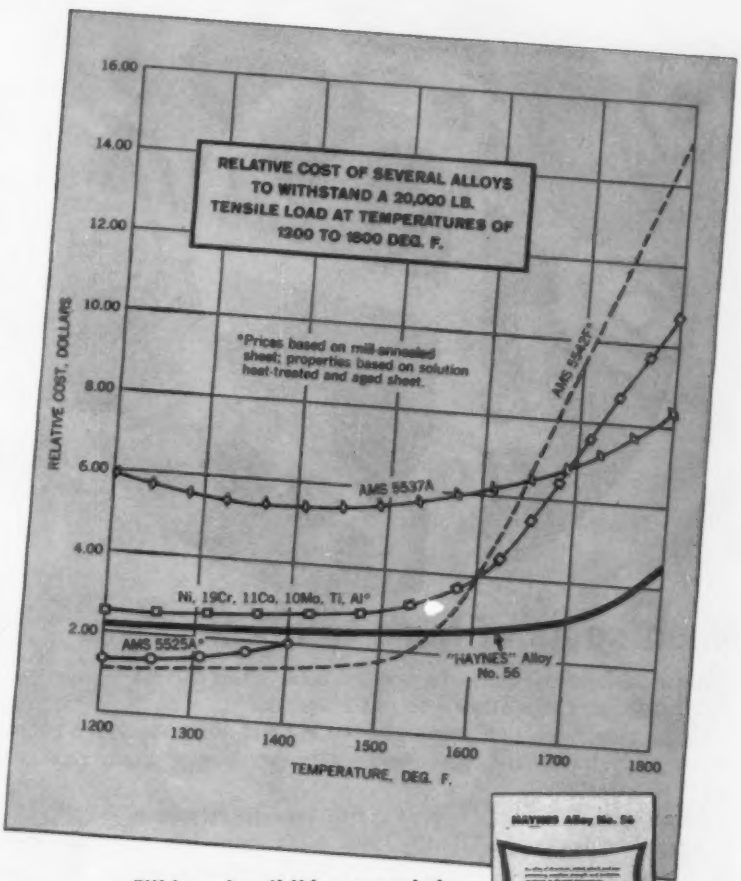

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Circle 2047 on Page 48-S

Corrosion . . .

by progressively higher degrees of supersaturation, and by a large temperature gradient between the solution and the walls of the heat exchanger. A small cold wall area will localize precipitation and greatly reduce it elsewhere.

The mass transfer of iron in liquid bismuth was presented in terms of the above steps. A high flow rate promoted a massive iron deposit, but a slow rate and high heat removal yielded a lacy structure. Introducing impurities, either to the solid or to the liquid metal coolant, may either accelerate the dissolution of the container material (as oxygen in liquid sodium accelerates the solution of steel), or such impurities may partially inhibit solution (as zirconium or titanium in mercury or liquid bismuth inhibit the attack on steel). The latter elements are absorbed on the iron surface, and form nitride and carbide films which retard the solution of iron. Relationships between the inhibiting film formation and the composition, heat treatment, and structure of steels were discussed. Steels which have the maximum nitrogen and carbon activity are most suited to corrosion inhibition. Inhibitors shift the rate controlling step from liquid diffusion to dissolution. They also increase the cold lag supersaturations required for precipitation to occur. Dissolution rate at the hot leg of a 1020 steel heat exchanger was extremely slow after as little as 0.04% Zr was added to the liquid bismuth.

The science of liquid metal corrosion in still in its infancy due to the lack of an adequate model describing what happens when a solid metal dissolves in a liquid one.

Corrosion by Fused Salt

Next, J. H. DeVan (Oak Ridge National Laboratory) lectured on "Corrosion of Metals by High-Temperature Fused Salt Mixtures". Fused salt mixtures have long been of interest to metallurgists both as fluxing agents and as baths for heat treating. With the advent of nuclear reactors, the containment of molten salts has taken on added importance. Attempts are now being made to employ various salt mixtures as coolants, carriers of fuel material, and as neutron barriers. Salts are useful because they remain stable under irradiation and have low vapor pressures at relatively high temperature.

Though hydroxide systems are also being investigated, the talk dealt mainly with the corrosive action of fluorides of sodium, zirconium and uranium in contact with Inconel. When these salts were tested in an Inconel heat exchanger, the metal surface lost chromium at the hot leg while the salt was being enriched in this element. Actually, the over-all process comprises the diffusion of chromium to the metal-fused-salt interface where it reacts with the fluoride ion to form chromium fluoride. In turn, that compound is transported to the cold leg where pure chromium precipitates. The rate controlling process is the diffusion of chromium to the depleted interface.

To improve the performance of the heat exchanger, it was operated at a lower temperature (to retard diffusion of chromium to the metal-fused-salt interface), the chromium content of the alloy was reduced,

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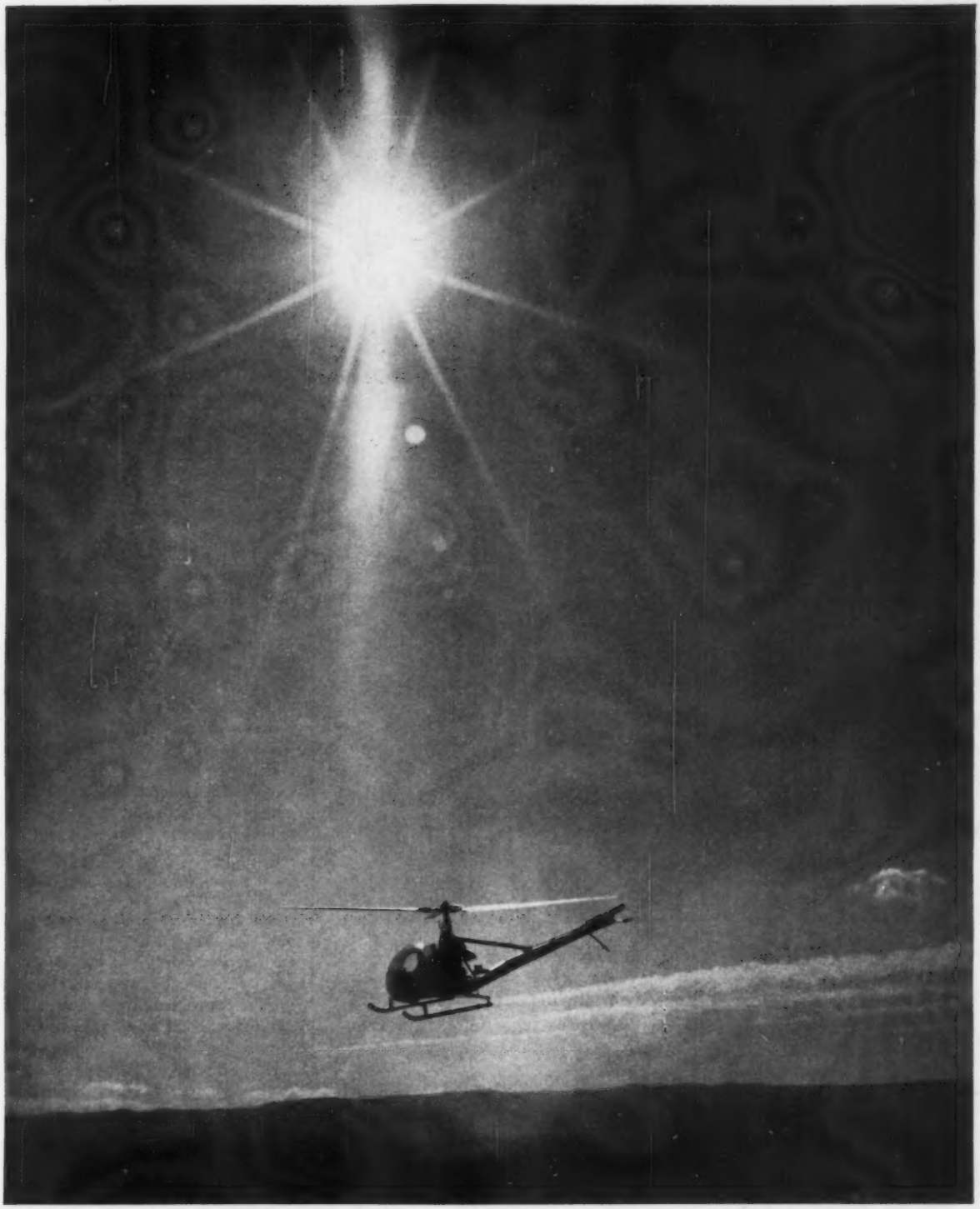

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Corrosion . . .

and enough chromium impurities were added to the salt to lessen initial solution of the chromium. The Inconel composition was changed from 15% Cr, 7% Fe, to 17% Mo, 5% Fe, 7% Cr, and the corrosion rate decreased from 0.013 to 0.005 in. loss per year.

In conclusion, corrosion of metals by fused salts pertains to the area of high-temperature corrosion, since in both cases the rate controlling step is the diffusivity of the component being attacked preferentially.

Solving Corrosion Problems

The last talk was given by F. L. LaQue (International Nickel Co.) who introduced his talk on "Specific Corrosion Problems and Their Practical Solutions" by saying that he spent most of his career solving unanticipated corrosion problems.

Oxidation problems were illustrated by tracing the history of the development of the heating elements for electric ranges. In this development, engineers soon found that a suitable alloy could not be selected on static oxidation test results alone. Rather, cyclic tests more closely simulated actual service conditions, and consequently were more meaningful. The reason? The oxide film which is protective at the operating temperature is likely to crack during heating and cooling cycles and thus be less protective.

The speaker also described a rather baffling case of pseudo-aqueous corrosion which involved poor color reproducibility in hosiery dyeing. This difficulty, which was attributed to corrosion of the dye vat alloy (in this instance, Monel), was solved after a long and tedious investigation tinged with luck. The presence of air in the vat during dyeing controlled the success of the operation. As long as air was available to the dye, no trouble occurred; however, placement of a tight cover over the vat caused trouble. (Under these conditions, the dye was being reduced.)

Another case involved corrosion of nickel in the pasteurization of milk. The strange behavior was finally explained on the basis that corrosion of the nickel occurred only during the period when the temperature of the milk was being increased.

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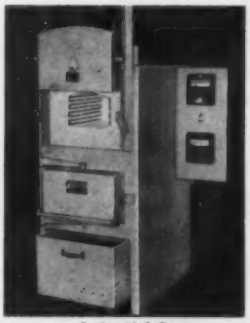

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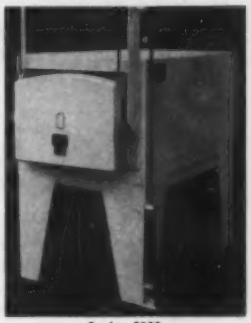
Ten models 2000° F and 2300° F range

All standard models include an automatic indicating controller and are wired ready to operate on standard line voltage. *Write for bulletins A-59 and B-59.*

Electra Products manufactures furnaces for semiconductor diffusion processes, sintering, glass annealing and processes requiring temperatures up to 3000° F.

Inquiries are invited—no obligation
Territories available for representatives



Series 2000

ELECTRA PRODUCTS CO. Montgomeryville, Pa.
Circle 47 on Page 48-B

FREE POWDERED METAL BOOKLET . . .

Gives cost-cutting hints, including:

- Illustrated description of Remet powdered metal process
- Design DO's and DON'T's for powdered metal parts
- Advantages and limitations of Remet process

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Gears • Pinions • Cams • Ratchets • "Oilless" Bearings • Bushings • Machine and Structural Parts in COPPER • BRASS • IRON • ALLOY STEEL • NICKEL SILVER • COPPER INFILTRATED IRON
Circle 50 on Page 48-B

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Quality FLAME HARDENING

FLAME HARDENED
MACHINE WAYS
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Valuable Technical Information
FREE
For The Asking
Circle 23 on Page 48-B

IDENTIFY PARTS FOR HEAT TREATING!

Markal
PAINTSTIK MARKERS
"M" and "M-10"

Mark any parts while cold, identify them after heat treating regardless of temperatures and oil or water quenchings. Use "M" up to 1600° F., "M-10" up to 2400° F.

WRITE ON LETTERHEAD FOR complete Paintstik information.

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3118 West Carroll Ave. Chicago 12, Ill.
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STOP CARBURIZING, DECARBURIZING, SCALING DURING HEAT TREATMENT!

Markal
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MARKAL "C-R" COATINGS will protect a wide range of metals at temperatures up to 2100° F. against carburizing, corrosion, scaling and the like. Coatings are easily applied, easily removed after treating.

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From the simplest to the most complex

Alumilite Anodizing

EXTRUDED ALUMINUM SHAPES To Your Specifications

Send for stock die catalog or send rough sketches for help with your design.

JARL EXTRUSIONS, INC.
Dept. MP, Linden Ave. • East Rochester, N. Y.

Circle 3 on Page 48-8

the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg

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GRIES INDUSTRIES, INC.
Testing Machines Division

Circle 5 on Page 48-8

MULTI MOTION DIES* .... FOR COMPACTING POWDERED MATERIAL TEST SPECIMENS ....

DL-1001 TENSILE TEST BAR MPA STANDARD 10-50

- Tensile Bars
- Transverse Bars
- Green Strength
- Bushings
- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

*PATENTED

HALLER, INCORPORATED
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Circle 51 on Page 48-8

Wiretex BASE TRAYS OUTLAST CAST TRAYS 3 to 1

Another example of how WIRETEX solves special parts holding fixture problems.

Tests at Ford's Indianapolis Steering Gear and Cold Heading plant proved Wiretex fabricated alloy trays saved many dollars, outlast other trays by more than 3 times. 26 months later, the trays were still in use, without replacement.

Call Wiretex for all your heat treating requirements to resist acid, heat, abrasion or exposure.

Specialists in Processing Carriers Since 1932.

Wiretex mfg. co., 20 Mason Street, Bridgeport 5, Conn.

Circle 24 on Page 48-8

RUST-LICK IN AQUEOUS SYSTEMS

Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

Send for Brochure: The ABC of Rust-Lick for Rust Prevention

RUST-LICK, INCORPORATED
755 BOYLSTON STREET
BOSTON 16, MASS.

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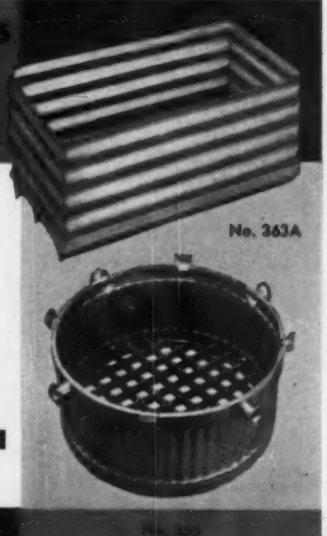
✓BASKETS ✓RETORTS ✓CARBURIZING BOXES ✓MUFFLES OF COR-WAL® CONSTRUCTION ARE CUTTING HEAT TREATING COSTS EVERYWHERE!

No. 358



No. 363A

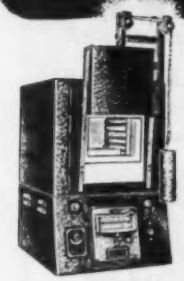
Cor-Wal construction developed by Stanwood engineers has proved its merit in many heat treating departments and commercial heat treating shops. The heat resistant, corrugated rolled alloy metal used in Cor-Wal construction has better loading carrying properties and provides better resistance to thermal stresses—works with the heat, not against it. Send for Bulletin 358.

STANWOOD CORPORATION
4817 W. CORTLAND ST., CHICAGO 39, ILLINOIS

Representatives in Principal Cities

Circle 22 on Page 48-8

HUPPERT ELECTRIC FURNACES AND OVENS
for Laboratory and Plant



BENCH MODELS

- Range: 300°F. to 2000°F.
- High temperature, heavy-duty Kanthal elements
- Multi-insulation
- Counter-weighted, tight-sealing door
- Operational pilot light
- Shipped ready to operate

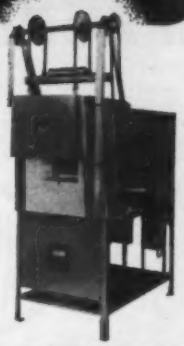
Model No.	Inside Dimensions Wide	High	Deep	KW	Prices 220 Volt Single Phase With Huppert Input Controller	With Electronic Prop. Controller
869	8"	6"	9"	4	$296.00	$480.00
11*	8"	6"	12"	4	306.00	518.00
12*	8"	8"	12"	6	382.00	590.00
12A*	8"	8"	18"	9	490.00	698.00

*For 2300°F. add $95.00 to No. 11 and No. 12, and $105.00 to No. 12A. No. 12A can be furnished for 3 phase at no additional cost. For floor model add $52.00 to above prices. No. 869 standardly supplied for 2200°F.

FLOOR MODELS
28 Standard Sizes

- Continuous operation to 1850°F.—intermittent to 1950°F.—for 2300°F. on special order.
- Complete with automatic electronic controller.
- Tight-sealing, wedge-type door.
- Multi-insulation for maximum efficiency.

Shipped Ready to Operate
Model No. 16 Illustrated $1050.00



Also Special Models for Specific Requirements. Special KR-Supers to 3100°F.

K. H. HUPPERT CO.
Manufacturers of Electric Furnaces and Ovens For A Quarter Century
6844 Cottage Grove Ave., Chicago 37, Illinois

Request new catalog on furnaces, ovens, data, prices.

Circle 53 on Page 48-B

All The Best

HEAT RESISTING ALLOYS

Ready When You Need Them

Please Send for Stock List and Literature

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Heat and Corrosion Resistant Alloy Specialists

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Phone WAlnut 1-4462

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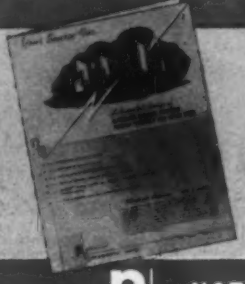
Phone CLifford 4-4616

Circle 44 on Page 48-B

FREE! ULTRASONIC CLEANING BULLETIN



Describes National Ultrasonic Corporation's:

- Applications Laboratory service. Your sample parts are cleaned ultrasonically and equipment and cost recommendations are made at no charge.
- STANDARDLINE medium power cleaners for all applications requiring average energy levels.
- HEAVYDUTYLINE high power cleaners for industrial applications requiring high energy density.
- NUclean® solvents and detergents especially formulated for ultrasonic cleaning.

NATIONAL ULTRASONIC CORP.
111 Montgomery Ave., Irvington 11, N. J.
ESsex 1-0550 • TWX NK 1030

Circle 31 on Page 48-B

Positive, Portable Lightweight (7 lbs.)

FINDS CRACKS INSTANTLY!

genuine **MAGNAFLUX Y-5 YOKE KIT**

Everything you need for Magnaflux testing: Yoke, gray dry powder and red prepared bath, cleaner, instructions, etc. Metal carrying case.

$195.00
Users net price F.O.B. Chicago

For maintenance overhaul, or even certain production inspection get the real Magnaflux in its most convenient form! Just right magnetizing power—light, easy to handle 7 lb. yoke, greatest accuracy and repeatability of results—Use indoors or out from 115V. A.C. or a 12V. battery—Handles hard-to-reach parts or areas.

USE MAGNAGLO and BLACK LIGHT

For the fastest, most sensitive tests, it can also be used with pressure spray cans of Magnaglo and black light. Kits available at modest cost.

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A Subsidiary of General Mills
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Circle 52 on Page 48-B

Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . .

ALLOYS
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AZ51
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ZK60
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M-1
ZK-20
Anodes

RODS ¼" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7¼" max
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Circle 1 on Page 48-B

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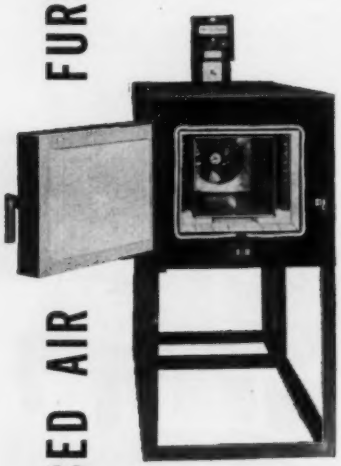

The Lucifer Furnaces, Inc., Series 4055 furnaces are manufactured in 25 standard models with 800° F. or 1250° F. maximum operating temperatures. These furnaces are designed for tempering, drawing, heat treating aluminum, and glass annealing. Each furnace is a complete unit . . . controls included. They are equipped with a large fan and motor to force circulation of air in the working chamber to insure maximum uniformity of temperature.

All electric heat treating furnaces by Lucifer feature • low initial cost • low upkeep • top production performance • minimum replacement downtime. For free engineering advice, parts, or product information . . . write, wire or call . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Penna.
Diamond 3-0411

Circle 26 on Page 48-B

SORGEL
Saturable Reactors

Saturable Reactor with tap changing transformer

Regulate and control electric ovens and furnaces more accurately and efficiently

Any amount of A.C. power from 1 Kva to 3000 Kva, single phase or 3-phase, at any voltage, can be controlled, regulated, and varied in stepless increments, with SORGEL Saturable Reactors.
The control can be a small manually operated hand wheel that can be placed in any desired location, or it can be automatically controlled, regulated and varied by a thermostat or any other instrument or device.
SORGEL reactors are designed to meet your exact requirements. Let us know what your problems and requirements are, and we will submit our recommendations with complete information.

Write for Bulletin 658.

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Also a complete line of dry-type transformers.

All standard and intermediate ratings, ¼ Kva to 10,000 Kva, 120 to 15,000 volts.

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Sales Engineers in principal cities

Consult the classified section of your telephone directory, under the heading "Transformers," or communicate with our factory.

Sorgel Electric Company

834 W. National Ave., Milwaukee 4, Wis.
Since 1916 devoted to creative engineering and manufacturing craftsmanship

Circle 16 on Page 48-B

GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF
Die Castings
SINCE 1922
Aluminum and Zinc

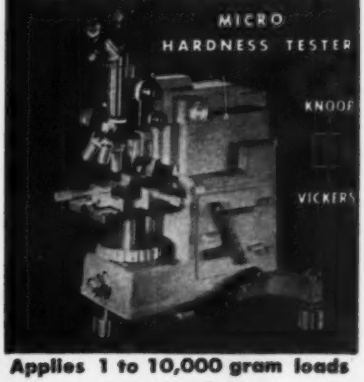
HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

Circle 41 on Page 48-B

KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads
Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

Circle 19 on Page 48-B

This new Super Satellite rotary diazo printer is acclaimed by draftsmen as the fastest white-printer in the low price field. Made by Grico, Inc., of Cuyahoga Falls, Ohio, its feedboard (A) and paper guide (B) are aluminum, extruded, polished and anodized by General Extrusions, Inc.

GENERAL EXTRUSIONS, INC.
4040 Lake Park Road • Youngstown, Ohio
Sales Offices at St. Louis, Pittsburgh, Chicago, Cincinnati, Cleveland and Chattanooga

Circle 2 on Page 48-B

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LFA LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

Circle 40 on Page 48-B

FREE
EPOXY GUIDE

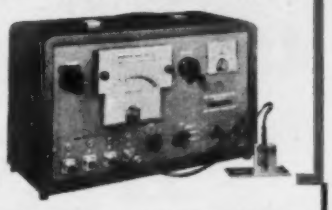
Interested in modernizing your production? Get this handy reference guide on epoxy adhesives, coatings, sealants, and plastic alloys . . . without cost or obligation.

Just write us on your company letterhead and ask for a complimentary copy of Resiweld Book #2.

RESIWELD
H. B. Fuller Co.
ST. PAUL , MINN.

Circle 34 on Page 48-B

DERMITRON
NON-DESTRUCTIVE COATING THICKNESS TESTER



FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

Circle 54 on Page 48-B

revolutionary • low cost
Newage
MICROHARDNESS TESTER

- permits direct, accurate readings corresponding to Vickers within a few seconds
- ideally suited for on-the-job production work
- eliminates a microscope, conversion charts, complicated tables
- for rapid and accurate checking of surface layers, thin sheets, flat springs, instrument parts, wire punches, etc.
- can be obtained in 1 kg or 2 kg loads penetrating as little as .000079" or .00016" respectively

NEWAGE INDUSTRIES, INC.
222 YORK ROAD
JENKINTOWN, PA.
TUrner 4-9494

Write, wire or call for full details

Circle 55 on Page 48-B

RAMCO
modular power spray washers

☑ MAXIMUM PERFORMANCE
☑ MAXIMUM ECONOMY

Proof? In this Ramco Bulletin . . . shows how you can create the *right* system for today's . . . and tomorrow's needs. *Send for your copy NOW!* Ask for Bulletin 659-1.

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd. • New York 59, N.Y.

Circle 42 on Page 48-B

LA-CO
Aluminum Soldering Flux
Now . . . Solder Aluminum with ordinary soft solders

- Use 60-40, 50-50, 40-60, 95-5 solders
- No new soldering techniques
- Non-acid . . . Self-cleaning

A major breakthrough in aluminum fabrication. Use ordinary soft solders . . . ordinary irons or torches. Remarkable fluxing action achieves perfect bond of aluminum and solder making possible the fabrication of aluminum to aluminum, copper, steel, stainless steel, galvanized iron, brass, etc.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Silver Solder Flux
Greater speed and economy for all silver soldering!

- Packed in tins
- Will not harden
- Non-acid . . . Self-cleaning

For all silver soldering in 1125° to 1700° F. heat range. Dissolves all refractory and non-refractory oxides . . . solder penetrates completely into all areas, for maximum strength without solder waste. Completely acid-free—will not pit or stain metals. Always-ready paste form . . . will not harden or crystallize.

Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Stainless Steel & Chrome Soldering Flux
Safer . . . Surer . . . Cleaner

- Doesn't stain
- Non-acid
- Self-cleaning

For soldering all stainless steel and chrome, including 300-400 Series, with ordinary soft solders. Requires no pre-cleaning. Acid-free formulation will not pit metals, leaves no stains. No buckling on even light gauge work. In liquid or paste form.

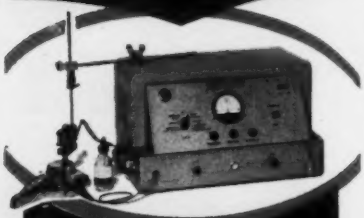
Write for sample, or engineering help on any fluxing problem.

LA-CO BRAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

Circle 4 on Page 48-B

TESTING PLATING THICKNESS?

15 Day FREE Trial
Guarantees Satisfaction



KOCOUR ELECTRONIC THICKNESS TESTER MODEL 955

Model 955 determines the thickness of decorative and heavy chromium, silver, tin, cadmium, zinc, brass, copper, nickel, lead, and other metallic deposits on various base metals. 90 - 95% accurate . . . Direct reading . . . simple operation.

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CHICAGO 32, ILLINOIS

Circle 56 on Page 48-B

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BOLTS & CAP SCREWS
SOCKET, SET & CAP
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SHEET METAL SCREWS
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Direct N.Y. 'phone Wisconsin 7-6310
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Circle 43 on Page 48-B

All that 'Quality' and 'Service' imply are yours with:

PRODUCTS OF TECHNIC RESEARCH for Precious Metal Plating

OROTHERM HT
Heat resistant 24Kt Acid Bright Gold, extremely low porosity, hard and ductile

OROSENE 999
24Kt Acid Bright Gold, tight grain, superior throwing and leveling power

HG BRIGHT GOLD
23+Kt Low Stress, Hard and Bright operates at room temperature, without free cyanide

INDUSTRIAL 24Kt GOLD
Ultra Pure Aqueous Potassium Gold Cyanide for soft stressless pure gold electroplates

RHODIUM SULPHATE T. P.
For High Purity, Low Stress fine grain Rhodium electroplating

PLATINUM N
A Superior Platinum concentrate for better plating

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A highly efficient soluble Palladium for plating at room temperature

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Available for experimental plating

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Provides anti-tarnish protection for gold, silver, and copper

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Immersion Tinning at room temperature

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Anionic detergent for free rinsing and cleaning

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Quality controlled and custom packaged to suit your requirements

INDIUM GOLD

ANTIMONY GOLD

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For semi-conductor plating

Information on these products, or on any problem involving the electrodeposition of precious metals, are available without obligation.

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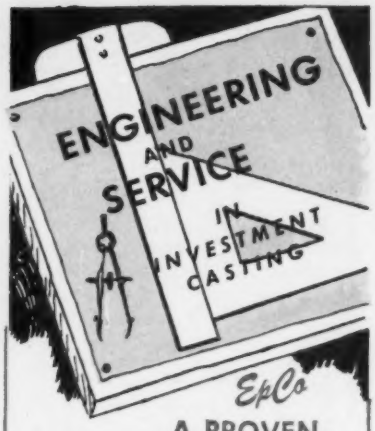
Our products are now distributed by

ENTHONE INC.
442 ELM STREET NEW HAVEN, CONN.

Circle 14 on Page 48-B



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A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING
Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

Circle 15 on Page 48-B

REVCO

ULTRA-LOW TEMPERATURE CABINETS

for
- Research
- Storage
- Seasoning
- Testing

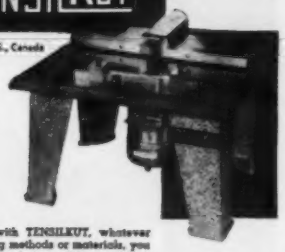
Seven styles...chest capacities from 1.5 to 6 cu. ft. Uprights up to 22 cu. ft. Temperatures to —140° are controllable within 1°. Immediate delivery.

For FREE folder, "Selecting a Low Temperature Cabinet," write Revco, Dept. MP-100.

Industrial Products Div.
REVCO INC
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle 12 on Page 48-B

TENSILKUT



Pat. Pend., U.S., Canada

● Now with TENSILKUT, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 2½ h.p. Write for free brochure.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut
Circle 11 on Page 48-B

HARDNESS TESTING
SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.
Circle 10 on Page 48-B

FREE

***the* QUENZINE STORY**

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .

ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio
Circle 29 on Page 48-B

Solve
Inspection
Sorting
Demagnetizing
Problems
with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI & SINGLE FREQUENCY EQUIPMENT

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WIRE ROPE EQUIPMENT

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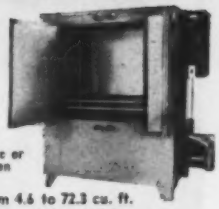

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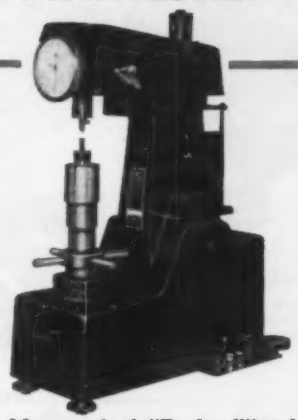

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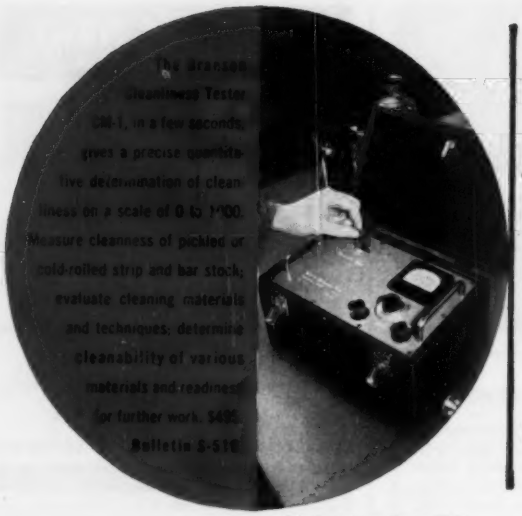

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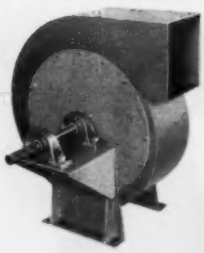

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Circle 58 on Page 48-B

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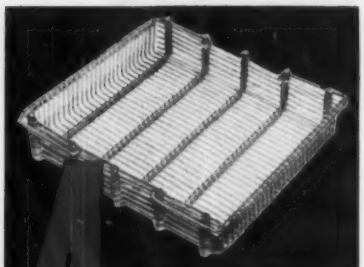

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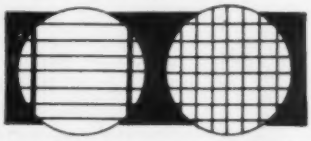

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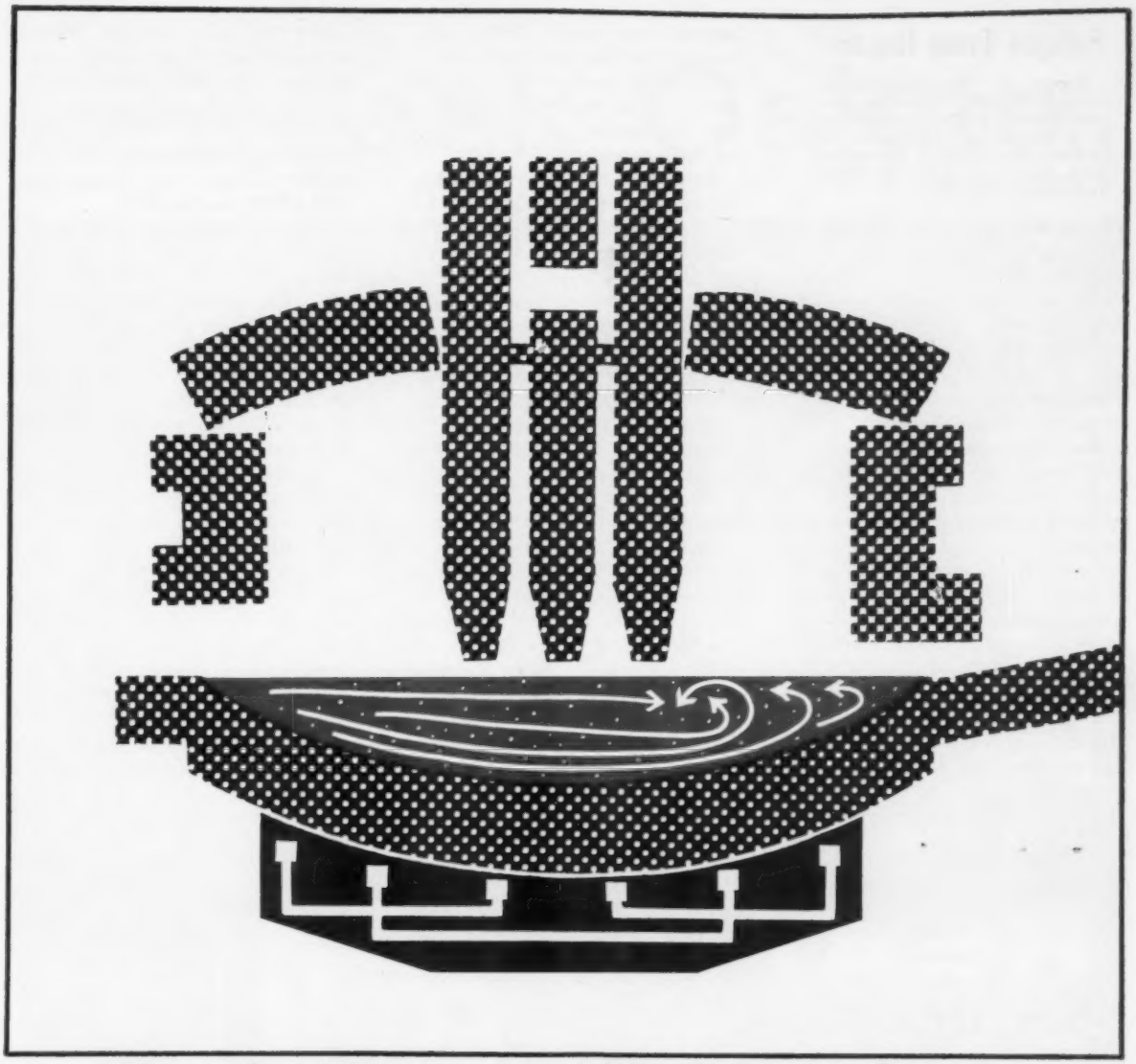

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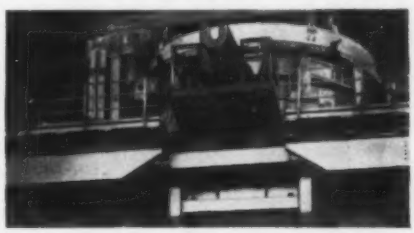

Circle 2020 on Page 48-B

Fatigue From Impact

Digest of "Investigation of Fatigue Under Repeated Impact", by N. N. Davidenkov and E. I. Belyaeva, *Metallovedenie i Obrabotka Metallov*, November 1956, No. 11, p. 4-10; Brutcher Translation No. 4719.

IN PREVIOUS WORK, the endurance limit under repeated impact has been expressed in terms of the energy per blow, and not in terms of stress. Here, the results from rotating beam tests have been compared with results from repeated impact tests in which the stresses were measured by strain gages.

Five alloy steels (with various heat treatments) were tested, the tensile strengths ranging from 90,000 to 290,000 psi. Conventional fatigue tests were made in a Schenck-type machine at 3000 rpm. on 0.22 in. diameter specimens. Repeated impact tests were made in an Amsler-type machine (modified to produce pure bending) on 0.4 in. diameter specimens. The specimen was rotated 180° after each impact, and there were five double impacts per second. The duration of each impact was about 0.001 sec., whereas the time for a half cycle in the Schenck machine was 0.01 sec. Hence, in the repeated impact test the deformation rate was roughly ten times as great.

In view of the time involved in the impact testing, comparisons between the results of the two types of test were made on the basis of 100,000 reversals only. The respective fatigue strength values at this endurance were determined from the best-fitting straight lines, obtained by the least squares method. The ratio of the impact fatigue strength to the conventional fatigue strength was determined in each case, and was designated the "dynamic coefficient."

Though such "dynamic coefficients" were all close to one (unity), certain trends were observed corresponding to the various structures produced by the different heat treatments. In the annealed condition, two steels gave values of 1.14 and 1.19, respectively. After normalizing or tempering at 580 to 600° C. (1070 to 1110° F.), the coefficients for six steels were in the range 0.97 to 1.01 (in one instance 1.04), indicating the almost complete absence of any effect of deformation rate. Medium tempering at 400 to 420° C. (750 to 780° F.) gave coefficients of 0.90 and 0.91 for two steels, and tempering at 190 to 200° C. (370 to 390° F.) gave values in the range 0.80 to 0.91 for five steels.

Various explanations of these results are put forward. One suggestion is that, with increasing strain rate, the carbide precipitation is retarded and its contribution to the over-all hardening effect reduced. This would act to lower the dynamic coefficient of the low-tempered steels, but would not affect the annealed steels.

Another possibility is the size effect, since the impact specimens were nearly twice the diameter of the rotating beam specimens. Earlier workers have shown that the more notch sensitive materials are less susceptible to size effect. In other words, the effect should be less, in low-tempered steels. Mirkin and Tsypkina (*Vestnik Mashinostroeniya*, No. 1, 1955) gave evidence to the contrary in a series of tests on martensitic and sorbitic steels with

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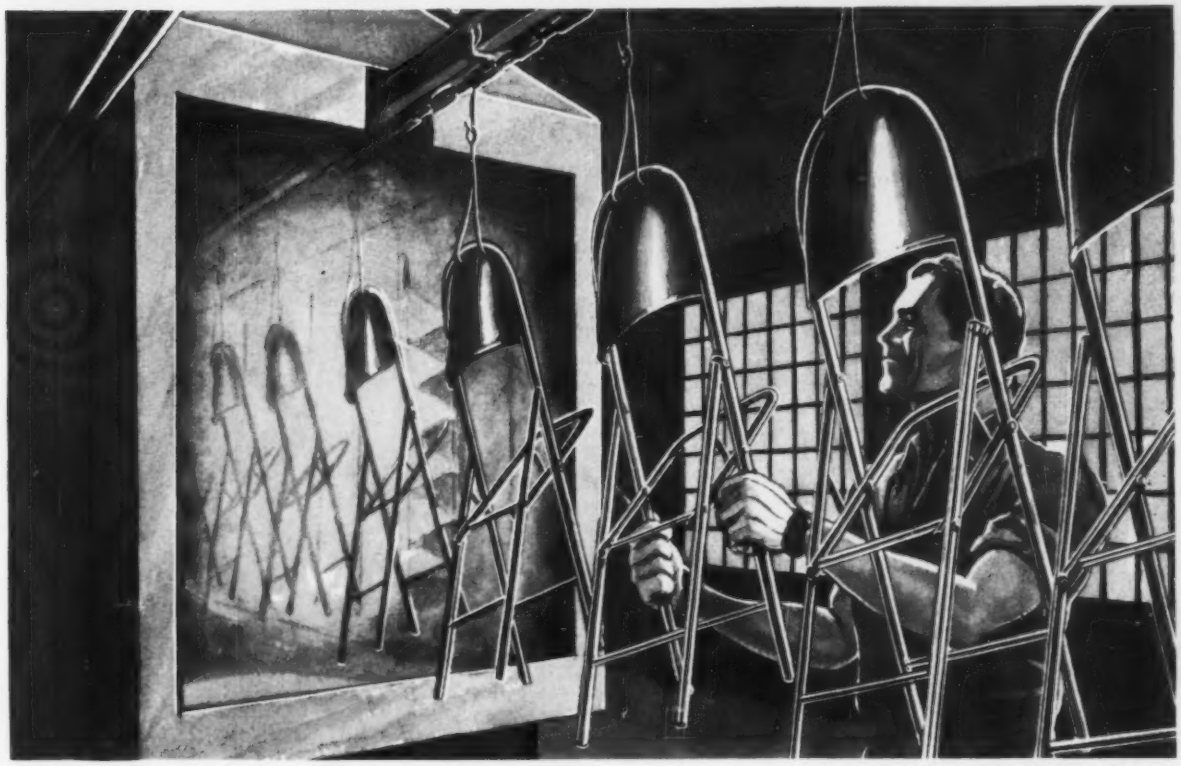

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Circle 2091 on Page 48-B

Fatigue . . .

a size ratio of just over two. In the martensitic condition, the size factor was 10 to 14% greater, and this result is comparable to the difference observed in the present investigation. Hence, the behavior of the low-tempered steels could be accounted for by the size effect. However, for the annealed steels the larger specimen gave higher results, which is incompatible with any previous work on size effect.

Mirkin and Tsypkina also reported a large variation in the microhardness of the low-tempered steel (35 to 55%), as compared with 7 to 15% for the high-tempered condition. If it is considered that the magnitude of the size effect is associated with the degree of heterogeneity of the material, their observed differences in size effect for the two conditions are explained.

In the present tests, the microhardness was measured on one steel only, and was found to vary by 9 to 10% for the low-tempered condition, 16% for the medium-tempered condition, and 20% for the high-tempered condition. This evidence, again, seems to discount the theory that the trends observed in the dynamic coefficient are due to size effect.

The authors conclude that while the variations in the dynamic coefficient with the different heat treatments can be explained on the basis of the reduction in carbide precipitation hardening at high deformation rates, the possible influence of size is not fully resolved; and further studies are desirable with specimens of the same diameter.

R. C. A. THURSTON

Effect of Boron on "Weld Decay"

Digest of "The Influence of Boron on the Nature of Carbide Separation in Austenitic Steels During Tempering", by V. V. Levitin, *Fizika Metallov i Metallovedeniye*, Vol. 7, 1959, p. 308.

IT IS WELL KNOWN that commercial steels of the 18 Cr, 8 Ni variety, containing about 0.06% carbon, even when locally heated as alongside a weld will lose their resistance to strong acids in that region, corrosion penetrating the metal along the austenitic grain boundaries. The explanation is that during such heating a chromium-rich carbide precipitates from solid solution, robbing the adjacent region of the chromium which confers corrosion resistance to the body of the metal. The steels Cr-Mn-Ni used in Europe, wherein manganese replaces a considerable portion of the other two alloying elements, are subject to the same disease. This publication describes briefly some experiments wherein small batches of the Cr-Mn-Ni steel were melted in an induction furnace, various amounts of boron added, cast and forged into rods. Susceptibility to intergranular corrosion after quenching from 1 hr. at 1740 to 2280° F. (950 to 1250° C.), and tempered 2 hr. at 1200° F. (650° C.) was appraised by metallography, boiling acid corrosion test, increase in electrical resistivity, and loss of metallic ring when struck.

Boron-free steels and those containing 0.002% boron possessed a continuous chain of carbides along grain boundaries after the tempering. In heats containing 0.004 to 0.010% boron, the carbide phase separates in fragments; considerable portions of the grain boundaries appear uncontaminated. Annealing temperature also seemed to have some influence: those samples quenched from the 1965 to 2100° F. (1075 to 1150° C.) range had isolated carbide particles, and those samples quenched from other temperatures in the experimental range had continuous carbide networks no matter what the boron content. Boron apparently prevents carbide formation in low-carbon steels — at least particles visible under an optical microscope.

The author quotes another Russian's theory that the atomic radius of boron, being less than that of atoms forming a substitutional solid solution in these austenitic alloys, and greater than that of the interstitial atoms, will locate itself preferentially at the surface of the grains (the austenitic grain boundaries). Therefore boron-rich boundary is less distorted than a lattice which is boron-free. Theory has it that carbon would diffuse in a region containing the optimum amount of boron at a lower rate than in one which has no boron. E. E. T.

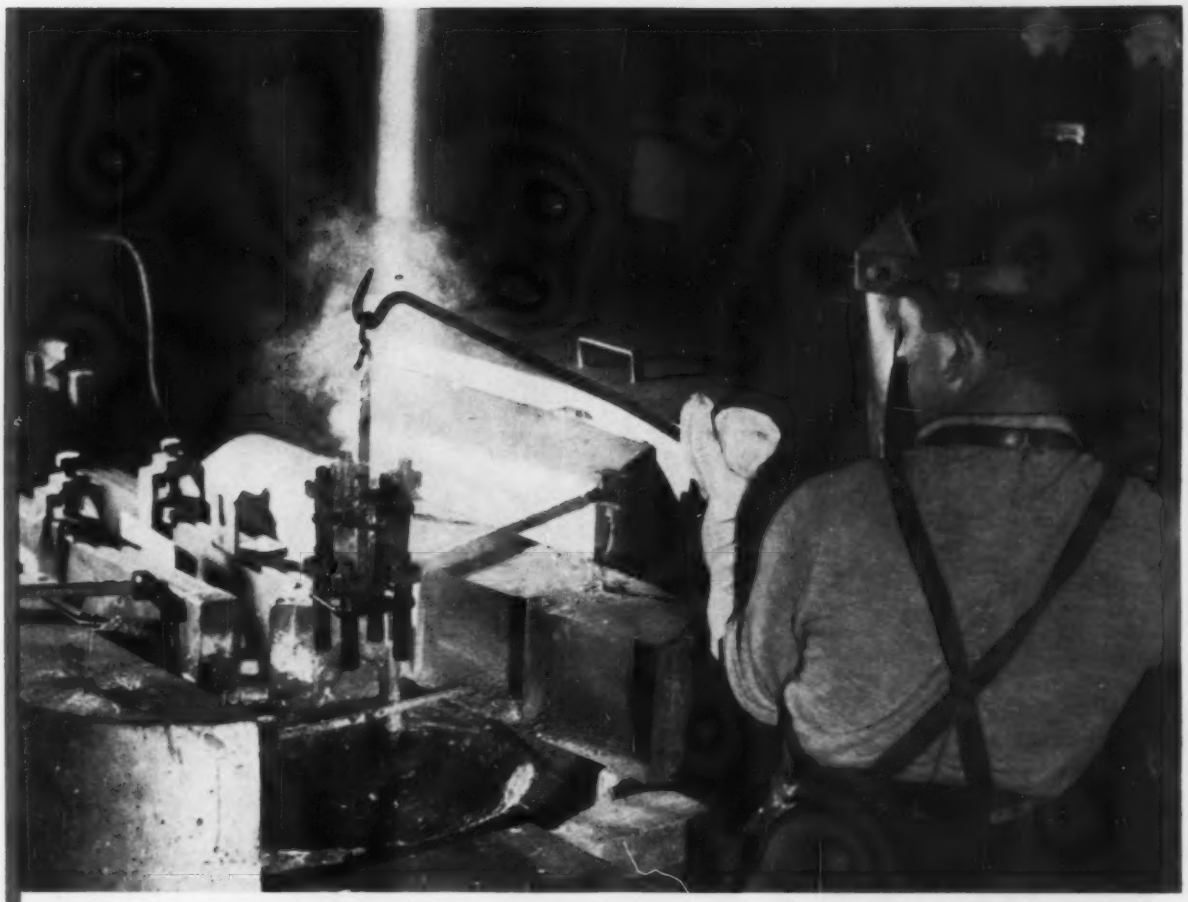

Photo by Etienne Bertrand Weill, Paris.
Perlitan carburizing bath in French metal plant.

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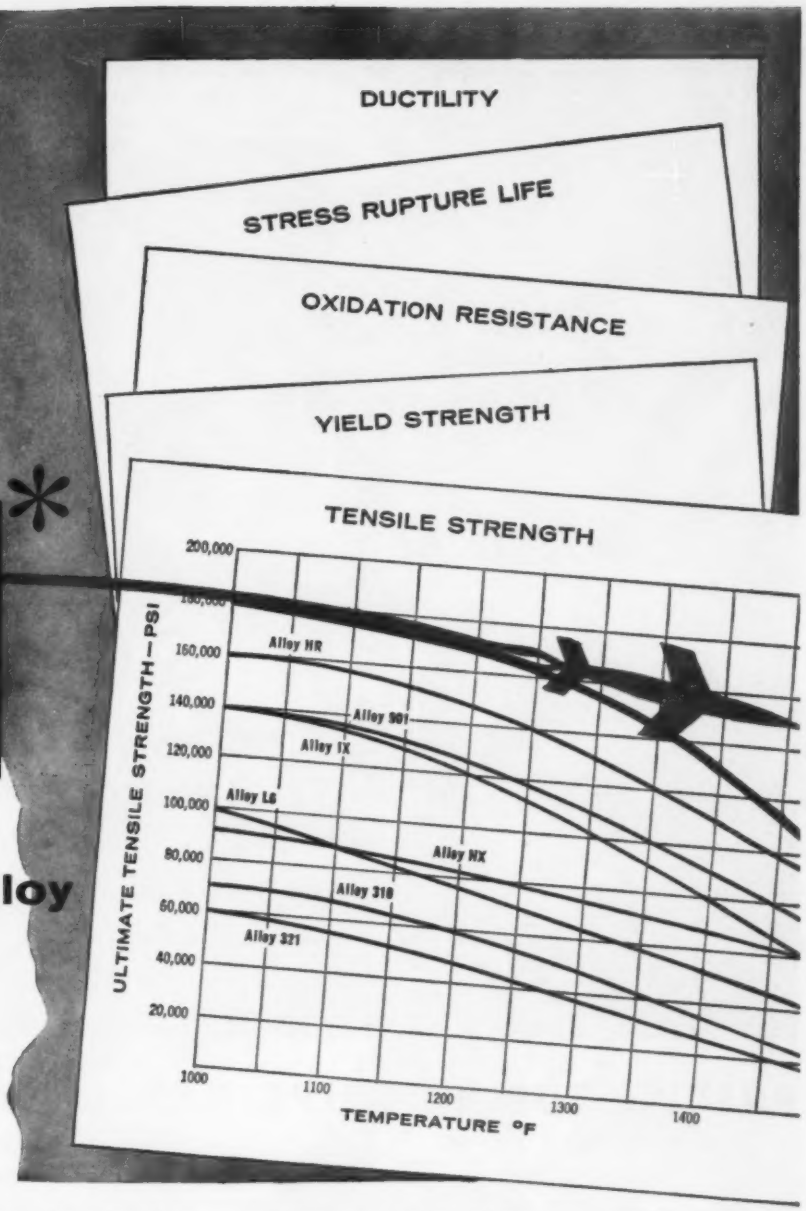

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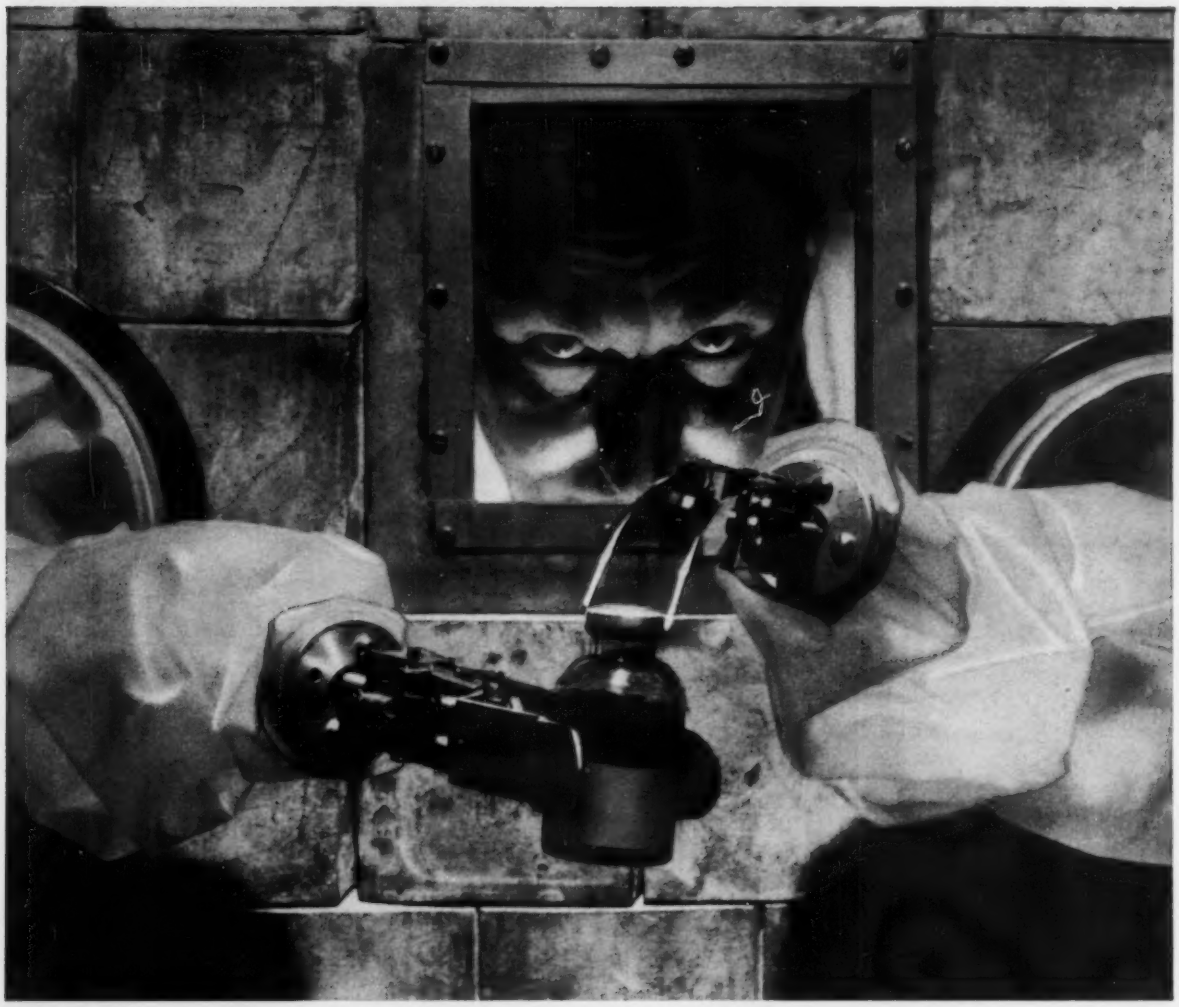

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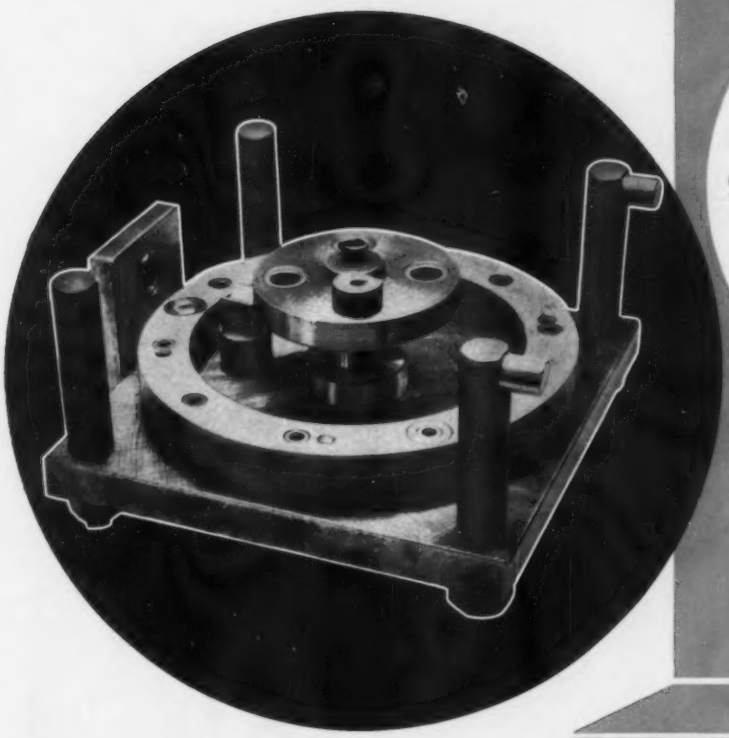

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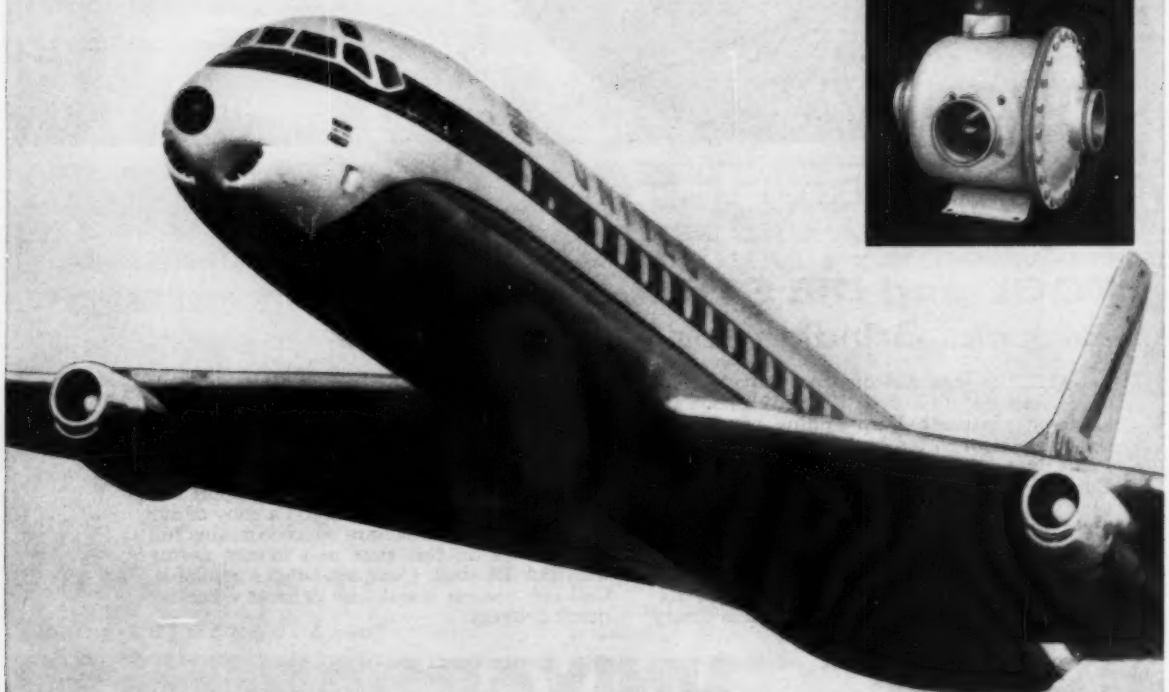
Big jet aircraft make money only when they are in the air. Every minute they are earthbound is costly. You just can't take chances on failure of aircraft engines from fuel contamination, or on failure of refueling equipment. That's why those parts of Brodie BiRotor refueling meters and control valves that come in contact with the fuel are chemically plated with KANIGEN nickel alloy.

Brodie BiRotor meters have been used for controlling aircraft refueling for many years, and their internal parts have been KANIGEN-coated ever since this highly accurate method of plating difficult or complicated surfaces was perfected.

Do you have a corrosion or contamination problem? Is it a small part like the Brodie meter housing? Or is it a surface as large as the inside of a 20,000 gallon tank car? Whatever it is, there's a way to solve your problems with KANIGEN chemical nickel plating. Write or phone the nearest General American office. *It pays to plan with General American.*



GENERAL AMERICAN TRANSPORTATION

KANIGEN DIVISION
CORPORATION
135 South LaSalle Street
Chicago 3, Illinois
Offices in principal cities

KANIGEN GENERAL AMERICAN

evidence of an evolution in steel processing

Here's a demonstration that sparked a revolution in steel processing. By slipping a piece of tissue paper through a model of an open coil we show how the gases get to the complete surface of the coil at once. This makes possible the exciting process of gas alloying by which carbon or nitrogen can be added or removed during the annealing operation. Called the most revolutionary advance in steel processing in our generation, its potential is unlimited. You can get complete data by calling in your Lee Wilson sales engineer or by writing direct.

Lee Wilson* ENGINEERING COMPANY, INC.

20005 LAKE ROAD • CLEVELAND 16, OHIO

HIGH PRODUCTION ANNEALING SYSTEMS

MAKE THE BEST METALS BETTER

* ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

Circle 2117 on Page 48-8

At Kennecott's new refinery... **Twin Heroult Electric Furnaces designed**

Copper cathodes are charged into the 13,500 KVA Heroult 90-ton electric arc furnace, one of two at Kennecott Refining's new plant south of Baltimore. American Bridge also fabricated and erected the plant's structural framework.

to keep 16,500-ton per month copper melt on schedule

Kennecott Refining Corporation's electrolytic copper refinery near Baltimore is the country's newest—a showplace of efficiency. One reason: a pair of 90-ton Heroult electric arc furnaces, each rated at 40 tons per hour.

Of nose-tilt design to facilitate launder pouring, they discharge a steady stream of molten copper (2150°) which is used in the horizontal casting of wire bars and the continuous casting of billets. One Heroult is on normal capacity operation while the other is a spare for use during relining, when the pre-heat furnace is down, or when additional production is required.

Copper cathodes are preheated to about 1400°F and door charged into the Heroult arc furnace on a peel arm crane. The three-phase power input utilizing ultra-high speed mechanical positioning for three 20″ electrodes with high-speed sensitive regulators maintains a constant arc above the copper bath for uniform temperature casting.

The two 90-ton Heroult arc furnaces can be tilted 40° forward and 15° backward. They feature mechanically positioned masts and special water-cooled skew-back roof rings that introduce water flow at the critical roof juncture to prevent warpage and burn out.

Whatever your arc-melt problem there is a Heroult electric arc furnace design for you. We've made them from 3 tons to over 200 tons capacity, for both swing roof top charge or door charge operation. They can accommodate induction stirring equipment, and can be designed for duplexing arrangements. And every Heroult is designed for maintenance by your own crew.

American Bridge has a complete electric furnace service that includes new installation, furnace modernization and part replacement. We'll be happy to quote on your building needs, too. Call our nearest office.

USS and Heroult are registered trademarks

American Bridge Division of United States Steel

USS

General Offices: 525 William Penn Place, Pittsburgh, Pa. Contracting Offices in New York, Philadelphia, Chicago, San Francisco, and other principal cities.
United States Steel Export Company, New York

This mark tells you a product is made of modern, dependable Steel.

Circle 2115 on Page 48-B

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Determining the Depth-Hardness of Alloy Steels

The hardenability of an alloy steel is usually measured by the depth to which the steel will harden under specific conditions of heating and cooling. One of the most conclusive methods of determining depth hardness is the end-quench hardenability test (ASTM A255). In essence, this test is as follows:

A 1-in. round specimen, approximately 4 in. long, is heated uniformly to the proper quenching temperature. The specimen is removed from the furnace and placed in a bracket; then a jet of water at room temperature is played on the bottom face of the specimen without touching the sides. This water jet is kept active until the entire specimen has cooled. Longitudinal flat areas are ground on opposite sides of the piece, and Rockwell C readings are taken at 1/16-in. intervals. The resulting data are plotted on graph paper, with the Rockwell C values as ordinates and distances from the quenched end as abscissae.

Experiments have shown that the points on the hardenability curve approximate the cooling rates at the centers of quenched rounds of various sizes; and that the hardness values at the centers of these rounds will correspond very closely with those shown at points on the end-quench hardenability curve.

In general it may be said that when end-quench curves for different steels approximately coincide, these steels can be treated similarly for equivalent tensile properties in sections of the same size.

A study of hardenability curves reveals that depth-hardness depends upon the amount of carbon present, the alloy content, and the grain size. Manganese, chromium, and molybdenum are the chief elements that promote depth-hardness, while nickel and silicon help to a lesser degree. It should be noted, also, that phosphorus promotes depth-hardness, while sulphur has a negative effect. In normal low-phosphorus and low-sulphur steels, the two elements neutralize each other.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 2116 on Page 48-B

For those jobs calling for

SUSTAINED HIGH TEMPERATURES

...in normally oxidizing atmospheres

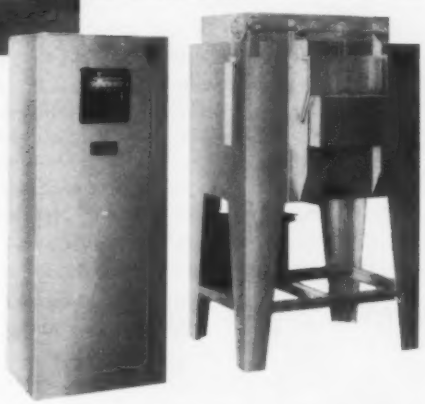
PERECO KANTHAL® SUPER ELEMENT FURNACES

up to 2900° F.
(Elements 3100° F.)

Above: Self contained, with furnace and control panel in a common base, this FGKS Series Unit is readily movable on ball-bearing pneumatic-tired wheels. Chamber size is 10" w. x 30" d. x 10" h. Door has adjustable stops. Saturable reactor package includes current limiting device. Temperature uniformity of ±5°F. is readily obtainable.

Left: Kanthal Super Elements, around an impervious Mullite tube provides a 12" long hot zone. Vertical-lift loading column is counterbalanced. A saturable reactor system and instrumentation are mounted in a separate matching control panel.

Below: This FGKS Series Box Type Pereco Unit, incorporating Kanthal Super Elements, is ideal for general purpose uses in normally oxiding or controlled atmospheres. Chamber size is 12" w. x 8½" d. x 6" h. Door is counterbalanced. All controls in a matching steel panel.



If your work calls for long periods of heat treating metal or ceramics at sustained temperatures up to 2900° F., Pereco Kanthal Super Element Furnaces offer you extra efficiency and operating economies. The elements do not increase in electrical resistance, thus permitting utilization of both old and new elements without adversely affecting thermal gradient or efficiency. Although maximum element life is obtained in normally oxidizing atmospheres they may also be used under neutral or reducing conditions. Other design features of these units provide for precise temperature control, uniform heating, flexible cycling, cleanliness, and maximum service life.

Pereco Kanthal Super Element Furnaces are built in a wide range of sizes and types (standard or with modifications) to meet specific individual requirements. Consult us.

Standard or Special Furnaces and Kilns
from 500° F. to 5000° F.

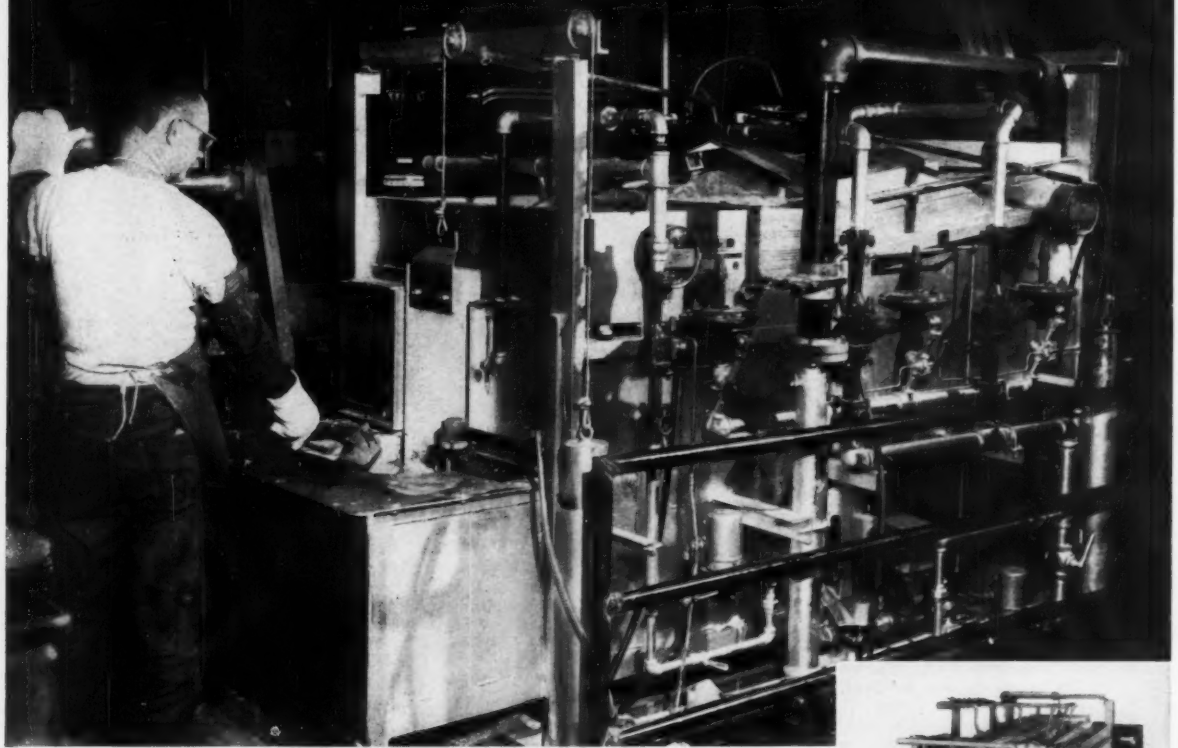
Write TODAY for get-acquainted bulletin

For work requiring temperatures not exceeding 2700° F., Pereco Silicon Carbide Element Units are the preferred standard in the field.

PERENY EQUIPMENT CO., INC.

Dept. Q, 893 Chambers Road — Columbus 12, Ohio

HIGH PURITY ALUMINUM MELTED WITHOUT CONTAMINATION IN NEW SELAS FURNACE



Selas single-well batch melting furnace accepts 30- or 50-lb pigs. 300 lb/hr capacity. Design incorporates door at charge end and over dip-well.

Selas double-well aluminum melter holds 1,000 lb of high purity molten metal; controls temperature within close limits.

Aluminum with 99.6% minimum purity is required by the electric motor industry for die-casting of rotors.

A leading manufacturer uses Selas dry-hearth melting furnaces to meet this rigid specification for high purity molten metal. The Selas Gradiation® method provides close control of heat input; roof-fired Duradiant® burners deliver fast, uniform heating and avoid flame impingement. Advanced design prevents transfer of silica from furnace refractory to molten aluminum.

Other proven benefits include the following:

- Metal temperature in holding section is maintained within close limits due to absence of any cold charges.
- Elimination of agitation and stirring keeps dross formation at absolute minimum.
- Operates with unusual fuel economy, continuously or intermittently, utilizing natural gas and air.
- Metal "frozen" during week-end shutdown re-melts quickly, without damage to furnace.

Selas aluminum melting furnaces are available in a wide range of capacities. At your convenience . . without cost or obligation to you . . a Selas field engineer will welcome the opportunity to survey your needs. For this personal service, or for further information about these furnaces, address your request to Mr. R. E. Buckholdt, Manager, Furnace Division, Selas Corporation of America, 311 Dreshertown Road, Dresher, Pa.

Gradiation and Duradiant are registered trade names of Selas Corporation of America

SELAS CORPORATION OF AMERICA
DRESHER • PENNSYLVANIA

HEAT AND FLUID PROCESSING ENGINEERS development • design • construction

lower your cost of possession

2 Nickel Alloy Steels provide

A simple plan to save money by Steel Standardization

How many types of steel do you normally use?

Chances are you should examine your needs for alloy steel to see how many can be satisfied with just two types, 4340 through-hardening and 4620 carburizing.

You are likely to find that most of your engineering requirements can be met with confidence when you *standardize* on these two general-purpose steels.

You simplify inventory and materials-handling. You save money in purchasing and production, too.

• 4340 stands alone among medium-carbon steels in its ability to provide maximum strength, ductility, toughness and resistance to fatigue in parts of medium to heavy section.

• 4620 is a carburizing type that has consistently proved itself the ideal steel for a wide variety of carburized parts. 4620 is easy to carburize and has a minimum tendency toward distortion in heat treatment.

Available From Steel Service Centers

Both 4340 and 4620 are stocked by Steel Service Centers from coast to coast, ready for off-the-shelf delivery in a variety of sizes.

When you have carried your standardization plan as far as you can and you still have specialized needs to fill, the right nickel steels are available to give you extra performance or even lower costs.

For a buyer's guide to Steel Service Centers that stock 4340 and 4620, and other nickel-containing grades, simply write Inco.

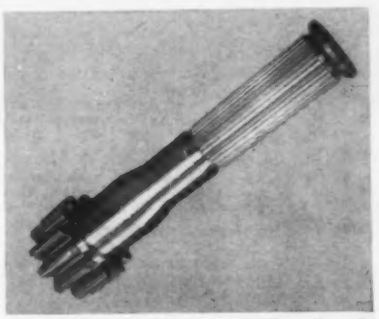
INCO TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

STEEL SERVICE CENTER INSTITUTE

Holding the Shippingport nuclear reactor's top head to its shell section is a job performed by 42 studs of AISI 4340. This through-hardening nickel steel provides essential strength and toughness.

Power-packed tractor features unique drive mechanism composed of regular gear transmission, clutch and torque converter with lock-up, utilizes nickel alloy steels in more than 25 components.



Swing shaft for giant power shovel made from 4340 nickel alloy steel for strength and toughness to take shock-loading in stride. This 9"-diameter, 36"-long shaft of 4340 nickel alloy steel transmits tremendous torque to a giant ring gear.

Sustained accuracy is assured in this heavy-duty milling machine by spindle and gear components of AISI 4340 and 4620 nickel alloy steels. They provide needed strength and wear resistance.

Circle 2119 on Page 48-B

NOW... these basic technical books are available from ASM at greatly reduced clearance prices

ORDER TODAY!

☐ **Acid Electric Furnace Steel-Making Practice,**
81 p. Describes commonly accepted melting methods; charging; nature of boil;; tapping; difficulties with low-carbon heats. **$1.00**

☐ **Alloy Constructional Steels,**
300 p. Data to help select steels for use in structures, machinery and equipment. **$2.00**

☐ **Behavior of Metals at Low Temperatures,**
112 p. Covers behavior of single crystals and pure metals; influence of mechanical and metallurgical factors. **$1.50**

☐ **Boron Steel,**
111 p. Proves practicability of using boron in place of expensive alloys. **$1.00**

☐ **Cast Bronze,**
448 p. A practical approach to the technology and engineering of bronze founding. **$3.00**

☐ **Casting of Brass and Bronze,**
185 p. A well-known foundryman's comments on melting, pouring, molds, mold dressings, deoxidizers. **$1.75**

☐ **Controlled Atmospheres,**
232 p. Chemical equilibrium as a guide in the prevention of oxidation of ferrous and nonferrous metals. **$2.00**

☐ **Copper and Copper Alloys,**
175 p. Fundamentals, including recovery; reduction; engineering properties of commercial copper alloys. **$2.00**

☐ **Corrosion of Metals,**
181 p. Principal problems involved in the corrosion of metals and factors contributing toward control. **$1.50**

☐ **Ductile Chromium,**
376 p. Reports on developments of chromium with good bend ductility at normal temperatures. **$4.25**

☐ **Fracturing of Metals,**
311 p. Fracture phenomena; effects of section size; fracturing of low-carbon steel; measurements for combined stress experiments. **$2.50**

☐ **Grain Control in Industrial Metallurgy,**
279 p. Fundamentals of recrystallization and grain growth in ferrous, copper, aluminum and magnesium alloys. **$2.50**

☐ **Heat Flow in Metals,**
144 p. Heat conduction and heat flow in the steady state; includes tables on heat flow. **$1.00**

☐ **High Temperature Properties of Metals,**
176 p. Stress-rupture testing; high-temperature fatigue testing; high-temperature oxidation testing. **$2.00**

☐ **Induction Heating,**
172 p. Includes surface hardening, through hardening and through heating. **$1.50**

☐ **Interpretation of Tests and Correlation with Service,**
198 p. Analyzes correlations and discrepancies between service performance and mechanical and wear tests and corrosion resistance. **$2.00**

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177 p. Experts report on machining wrought and cast alloys, tool steels, and nonferrous metals. **$1.50**

☐ **Magnesium,**
266 p. Extraction; structural design; castings; wrought alloys; corrosion and protection. **$1.75**

☐ **Mechanical Wear,**
387 p. Discussed ably and with understanding by American, British and Dutch experts. **$3.25**

☐ **Metal Interfaces,**
335 p. Describes the advances of last several years in one of the most important branches of physical metallurgy. **$3.00**

☐ **Metallurgy and Magnetism,**
156 p. Magnetic theory and definitions; magnetic materials; factors affecting magnetic properties. **$2.00**

☐ **Nonmetallic Inclusions in Steel,**
130 p. Nature and origin of common types of nonmetallic inclusions; methods of prevention and elimination. **$2.00**

☐ **Properties of Metals in Materials Engineering,**
170 p. Fundamental concepts, including application of fatigue data to machine design; stress in aircraft engines; design for energy absorption. **$2.00**

☐ **Residual Stress Measurements,**
210 p. Effects of these stresses, their measurement, relief and redistribution. **$2.00**

☐ **Sleeve Bearing Metals,**
256 p. Veritable encyclopedia on selection and properties, applications. **$2.50**

☐ **The Story of Magnesium,**
258 p. A non-technical account of production, fabrication and uses. **$1.50**

☐ **Structures and Properties of Mild Steel,**
222 p. Influence of elements; mechanical properties; age hardening; strain hardening; cold rolling and annealing. **$2.00**

☐ **Structure of Cast Iron,**
154 p. Primary structure and graphitization; influence of cooling rate; undercooling; inoculation. **$1.50**

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236 p. Enjoyable historical commentary by the inventor of stainless steel. **$1.50**

☐ **Utilization of Heat-Resistant Alloys,**
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213 p. Details the approach on how to answer this question. **$2.00**

☐ **Zirconium,**
354 p. Comprehensive, from ore dressing to fabrication and final uses. **$5.00**

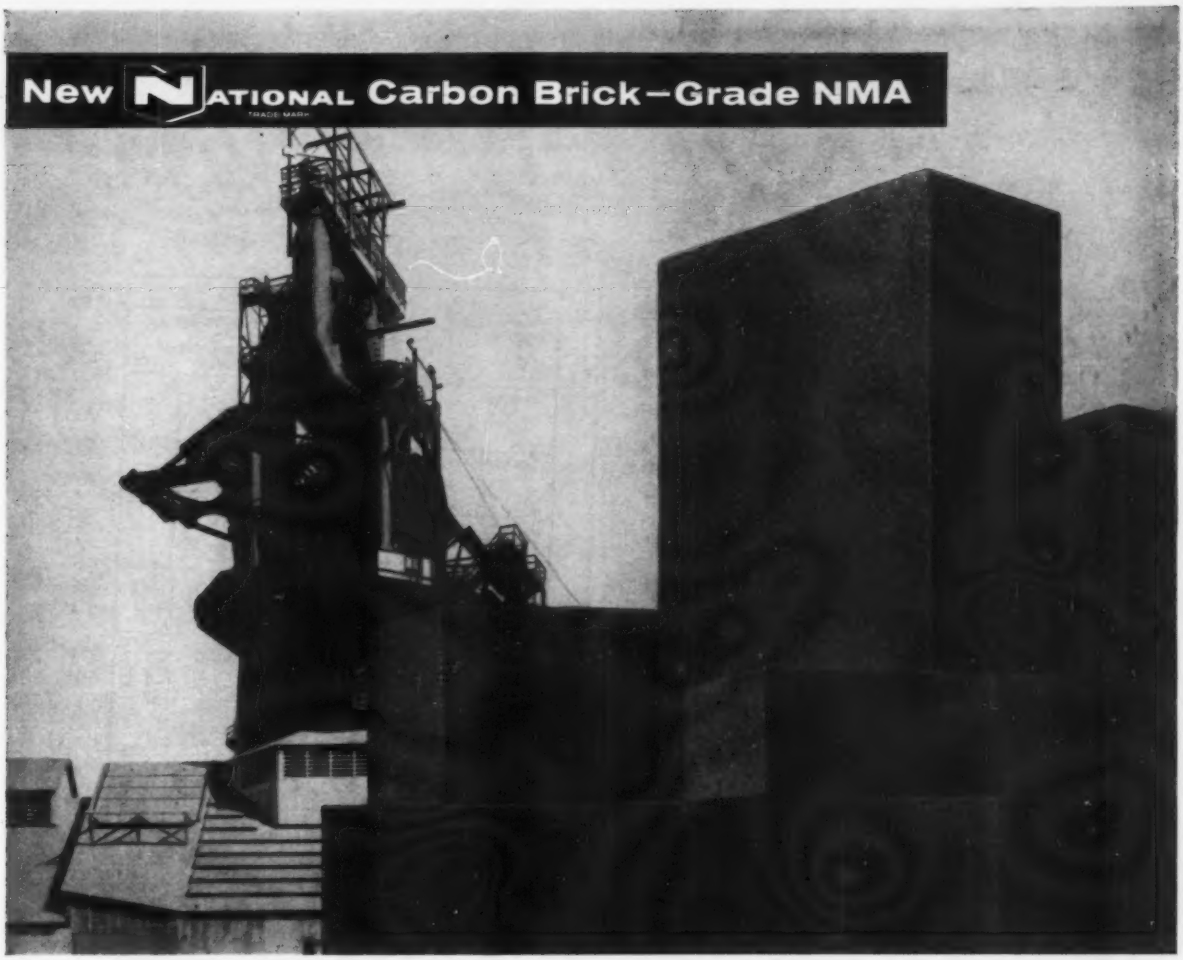
Use this entire page as your order form by tearing it out, checking the books you want, filling in your name and address. Mail to American Society for Metals, Metals Park, Novelty, Ohio

Name _____

Address _____

_____

☐ Check enclosed ☐ Bill me later



ANTHRACITE BASE GRADE NMA BRICK IS FAR SUPERIOR TO CONVENTIONAL REFRACTORIES!

This outstanding refractory material is especially designed for **Blast Furnace Linings.**

Grade NMA brick offers:

- **LOW PERMEABILITY** — 100 times less than conventionally produced anthracite carbon brick.
- **INCREASED DENSITY** — 6% higher than conventionally produced anthracite carbon brick.
- **HIGH THERMAL CONDUCTIVITY** — 7 times better than ceramics.
- **DIMENSIONAL STABILITY AT ELEVATED TEMPERATURES** — retains dimension to 5000°F.
- **RESISTS ALKALI ATTACK** — characteristic of NMA processing.
- **UNIFORM HEAT TRANSFER RATE** — maintains same rate throughout lining life.

Grade NMA brick is available from 4½" x 2½" cross section to 9" x 4½" cross section in up to 18" lengths.

Please send details on Grade NMA brick.

Name_____

Position_____

Company_____

Street_____

State_____

"National" and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY
Division of Union Carbide Corporation • 270 Park Avenue, New York 17, New York
IN CANADA: Union Carbide Canada Limited, Toronto

UNION CARBIDE

Circle 2120 on Page 48-B

CARBORUNDUM'S Data sheet

TECHNICAL INFORMATION ON SPECIAL REFRACTORIES

Comparative tests help determine

HOT STRENGTH

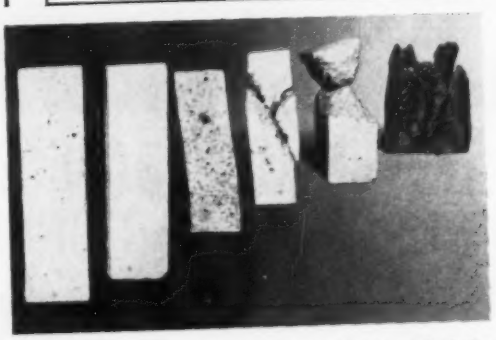
Studies of hot strength — or the ability to stand up under load at elevated temperatures—are a primary requirement in the selection and application of practically all refractories. The need for accurate data becomes all the more important as operations move to higher and higher temperatures, or where long periods of soaking heats are involved.

Information available from Carborundum includes compressive load tests, covering short duration and sustained periods, to indicate load-carrying capacity. Transverse load tests also provide valuable information — particularly, for applications where large spans of refractory shapes are unsupported or must carry a heavy furnace charge.

Engineering assistance can be given in evaluating the various factors affecting operation and in applying Carborundum's refractories to your job. Please feel free to ask any questions that may occur to you.

SUSTAINED LOAD TESTS

	Load, Psi.	Deformation After 100 Hr., % Temperature, Deg. F. 2192	2462	2732
Fireclay	6.25	0.30	3.9	—
	12.5	0.23	4.3	—
	25	0.32	11.3	—
	50	0.46	over 10.3	—
Semi-silica	6.25	—	1.19	—
	12.5	—	3.14	—
	25	—	5.03	—
	50	1.19	—	—
Silica	6.25	—	—	—
	12.5	—	—	Nil
	25	—	—	0.13
	50	—	—	0.25
High-alumina-fireclay	6.25	—	2.8	—
	12.5	—	2.4	—
	25	0.87	7.7	—
	50	1.30	9.9	—
Alfrax® "K" brick	6.25	—	+0.20	2.51
	12.5	—	+0.04	3.73
	25	—	0.25	8.68
	50	—	1.08	10.58
Monofrax® H brick	6.25	—	—	—
	12.5	—	—	—
	25	—	—	—
	50	—	—	0.36
Carbofrax® brick	6.25	—	—	0.40
	12.5	—	—	0.40
	25	—	—	0.58
	50	—	—	0.78



Comparison of hot strength of various refractories held at 3128 F for 1½ hrs under load of 25 psi shows CARBOFRAX® silicon carbide brick undeformed (extreme left) and MULLFRAX® electric furnace mullite brick (second from left) with less than 1.4% contraction. Other samples shown are commonly-used refractories in various stages of deformation. One on the right failed at 3002F.

HIGH TEMPERATURE, SHORT DURATION LOAD TESTS

Refractory	Max. Expan. at Temp. °F	Start Rapid Contr. °F	Held Temp. Max. °F	Held Temp. Aver. °F	% Linear Cold Contr.	Cold Length
Mullite brick	2561-2795	2867	3137	3128	14.3	7.75"
Mullfrax® W brick	2552-2768	None	3128	3119	1.31	8.943"
Carbofrax® A brick	2534-2714	3092	3146	3137	0.78	8.915"
Chrome magnesia brick	2597-2741	2975	Crushed at 3002		—	"Sheared"
Fireclay brick	2642-2660	2732	Crushed at 3002		—	6.75"
Fireclay brick	2462	2561	Crushed at 2993		—	6.6"
High alumina brick	2561-2624	2642	Squashed at 3011		—	6.7"
Silica brick	2795-2903	None	Crushed sharply at 2948		—	"Sheared"
Magnesia brick	2327	2507	Crushed at 2552		—	"Sheared"

Write today for your free copy of "Super Refractories by Carborundum." The address: Dept. M-110, Refractories Division, Perth Amboy, New Jersey.

For engineered refractories, count on **CARBORUNDUM®**

JUST OFF THE PRESS

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91 PHOTOS and DRAWINGS
3 YEARS of EDITING

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COMPLETELY NEW SOURCE BOOK

includes annotated bibliography
reporting concisely on all writings about Indium properly indexed and sectionalized for reference.

This new reference book on Indium will find its place in hundreds of university and technical libraries in many countries. It will be a worthy companion to research-minded engineers — everywhere!

Write for information bulletin today.

25 INDIUM

SINCE 1934 PIONEERS IN THE DEVELOPMENT AND APPLICATIONS OF INDIUM FOR INDUSTRY

THE **INDIUM** CORPORATION OF AMERICA
1977 LINCOLN AVENUE
UTICA, NEW YORK

Circle 2123 on Page 48-B

NOW BASIC METALLURGY II

NEW COMPANION VOLUME TO FAMED BASIC METALLURGY I

This easy-to-read and practical book describes the equipment and its use for metallurgical operations. This is a practical guide to metallurgical equipment, test and techniques.

Well-illustrated with 67 pictures, 17 pull-out data sheets and 37 charts and graphs, Basic Metallurgy II contains a comprehensive 8-page index for handy use plus 68 references to other authoritative sources.

Table of Contents

PURPOSE AND KINDS OF TESTING
TENSION TESTING MACHINES
HARDNESS TESTING
OTHER MECHANICAL TESTS
NONDESTRUCTIVE TESTING
MACROSCOPIC TESTING
MICROSCOPIC INVESTIGATION
PYROMETRY
HEAT TREATING EQUIPMENT
PREPARED ATMOSPHERES FOR HEAT TREATMENT
CORROSION TESTING
MISCELLANEOUS TESTING

$10.00...232 Pgs. PLUS 17 Data Sheets...Red Cloth Binding

ASM Technical and Engineering Book Information Service
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Enclosed please find $..... for copy(s) of Basic Metallurgy, Volume II.
Or: Bill me ☐ Bill Company ☐

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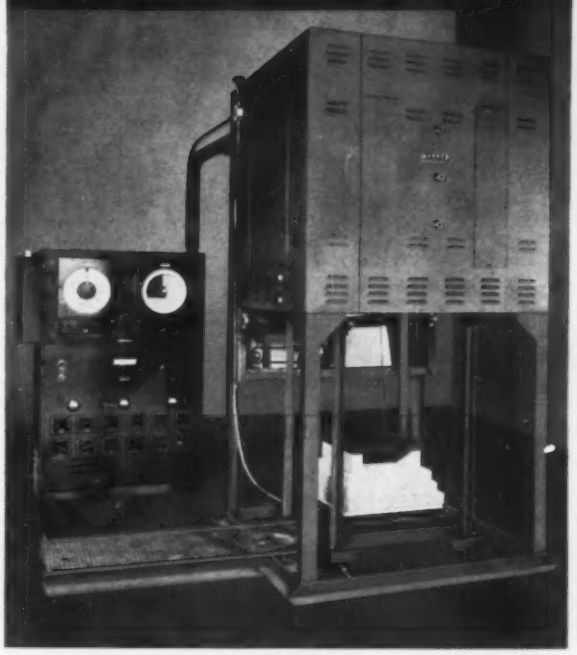
Company .....

±2° ACCURACY UP TO 2700° F.



Model NMR-12E non-metallic resistor Harrop furnace. Mechanical or hydraulic elevator. Shuttle hearth also available.

Harrop electric atmosphere furnace is designed for precision testing and small parts production

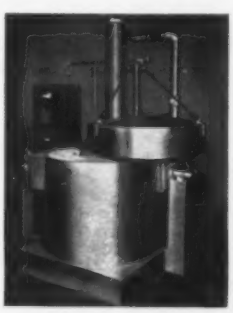
Here is a furnace that is adaptable to many uses, such as crystal growing and firing of ferrites, titanates and similar electronic ceramic parts. Instrumentation can be supplied for any firing requirement, both in respect to control and to control forms affecting the time-temperature-atmosphere relations.

Harrop NMR Series elevator furnaces are available in two firing chamber sizes . . . 12″ x 16″ x 12″ and 20″ x 26″ x 20″. They fire rapidly to ± 2° F. accuracy within their range of 2000° to 2700° F. Cooling can be quickly accomplished by an external sealed heat exchanger to follow a program controller.

Within the area of Harrop's broad scope and varied abilities, you may well find the solution to your problem relating to

- the controlled application of heat
- the measurement of the effect of temperature

To secure a prompt, objective evaluation of Harrop's ability to help you . . . write Dr. Robert A. Schoenlaub, Director of Research, Harrop Precision Furnace Co., 3470 East Fifth Avenue, Columbus 19, Ohio.



Gas-fired Harrop furnace, GFHT Series, available in both floor and elevator types. Range of setting spaces from 8" dia. and 14" height to 36" dia. and 48" height. Standard temperature range to 3300° F., higher if desired.

HARROP PRECISION FURNACE CO.

Dept. M (formerly Harrop Electric Furnace Division)
A Division of Harrop Ceramic Service Co.

Circle 2122 on Page 48-B

THE LITHIUM REACTOR

CURRENT INFORMATION ON LITHIUM CHEMISTRY AND METALLURGY

LITHIUM-LEAD EUTECTIC SHOWS IMPROVED MECHANICAL PROPERTIES

Small Addition of Lithium Makes Big Difference in Strength and Other Important Properties

Lithium's unusual alloying potential is demonstrated once again in lead-lithium alloys where small quantities of lithium enhance many of lead's more useful properties.

Lithium is only slightly soluble in lead and forms one practical eutectic at .69 weight per cent Li. Above one per cent Li, the alloys formed are too brittle and friable to be useful in any modern application. Several samples of the 99%-lead—1%-lithium material have been made up and tested. Some of the resulting comparative figures (see chart below) show definite improvement offered by the alloy over commercial lead.

	Pb (99.73%+)	99% Pb —1% Li
Ultimate tensile strength	2000 psi	5770 psi
Tensile yield stress	800 psi	4330 psi
Shear strength	1825 psi	3960 psi
Elongation	47%	51%
Reduction of area	100%	74%

Other investigations show the stress rupture life of the eutectic to exceed 1000 hours at room temperature and 1000 psi load. The elongation was 1.8%. Loadings of 2000 psi and over severely reduced the time factor.

The hardness of the eutectic was reported as 15.0 compared to 4.5 for unalloyed lead (diamond pyramid test).

The eutectic is somewhat susceptible to oxidization. A gain of 0.03% weight was recorded after 500 hours at 230°F. However, immersion tests over three-week periods showed no change at 70°F in water, styrene, or amyl benzene.

Contact corrosion tests with 2024T aluminum, 1010 steel, brass, and 321 stainless steel showed no attack on the contact metal after 3 weeks at normal temperature and humidity. The eutectic gained 1% weight in these tests.

The eutectic has been shown to suppress secondary gamma-ray production.

New Lithium G-3 Applicator Devised for Small Foundry Melts

Foundry Tests Prove New Applicator Superior

The successful lithium inoculation of cuprous melts requires deep submersion of the lithium cartridge. This is essential because the lithium, with a density which is but $\frac{1}{16}$ that of copper, might otherwise rise to the surface and burn without combining effectively with the gas-forming elements in the melt.

Lithium Corporation's concern with the convenience and efficiency of introducing lithium cartridges led to the development of the G-1 and G-2 multi-purpose applicators which were introduced last year. Finding widespread interest among foundrymen, these applicators are especially well-suited for inoculating large melts.

Small foundry melts, however, particularly those of 200 pounds or less, require a more delicate approach. LCA has now developed the G-3 applicator specifically designed for use in small operations.

The G-3 applicator is comprised of a two-foot-long, one-inch-diameter graphite rod. At the lower end is attached a two-inch-square, four-inch-long graphite block. The bottom face of the block is notched to receive one or more LCA lithium cartridges. The cartridges are secured in the notch by one or two wraps of copper wire. The upper end of the rod is fitted with standard pipe threads for the attachment of a handle or an ordinary pipe extension.

The G-3 applicator has been foundry tested and proved to be superior to other models in quality and workmanship. Its lesser volume of higher quality graphite reduces heat absorption and resists the tendency to burn when the rod is withdrawn from the melt.

LITHIUM IN BRIEF

Alloying and casting studies on Pb-Li eutectic also lists mechanical and corrosion properties of the alloy. (1959)

•

Mass transfer in liquid-lithium forced-convection loops studied and solution rate constants tabulated. (2499) Effects of radiation-generated helium and tritium on the properties of Al-Li and Mg-Li alloys have been reported. (2514)

•

Clinical study discounts potential toxicity of Li ion in human system. (2559)

•

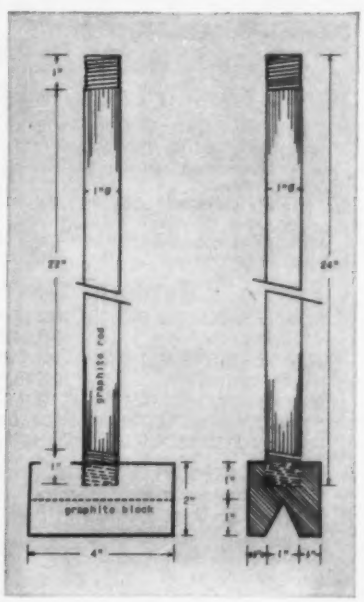
The properties of lithium ferrite monocrystals with respect to magneto crystalline anisotropy and ferromagnetic resonance are discussed in literature. (2993-2994)

•

The effect of molten metals on stressed solid metals with emphasis on the effect by lithium has been reported. (3232)

•

The structural aging effect of aluminum-copper-lithium alloys, the mechanical properties of aluminum-lithium alloys, and the theta phase in magnesium-lithium-silver alloys are discussed in recent AIME publications. (3248, 3249, 3250)



New LCA G-3 applicator

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Catching the Drift of Gyro Bearings

The fantastic accuracies needed by inertial guidance systems for space flight depend on the suppression of gyro drift, the tendency of a gyro to precess from minutely occurring internal torques. Particularly puzzling has been the problem of "jogs," or sudden axial shifts, within gyro spin-axis bearings. Shifts of but one ten-millionth of an inch can cause serious steering error.

Specialists at the GM Research Laboratories have found that the real key to drift lies in the thickness and distribution patterns of bearing lubricating films. Only a tenth of a milligram of oil – equivalent in volume to less than two-thousandths of a drop of water – is required in a gyro bearing, but even this amount unevenly distributed may cause jogs.

Conducting unique studies of single bearings apart from rotor assemblies, GM Researchers use a hydrostatic spindle and special instrumentation to take film-thickness measurements they compare with hydrodynamic theory. Jogs, due to excess oil supply, have been analyzed in relation to surface oil transfer and separator feed control, ball spin orientation, displacement, and differential heating and ball wander.

This experimental and analytical approach is achieving progress toward jog-free, stably distributed, and suitably thick oil films required in high-precision bearings. It is a further example of the critical and advanced research General Motors carries out in seeking "more and better things for more people."

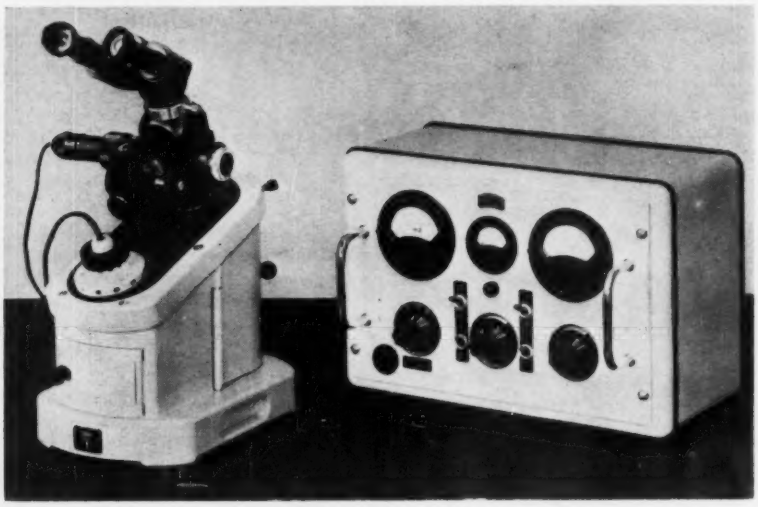
General Motors Research Laboratories

Warren, Michigan

The fluoresced streaks show the disturbed "wake" of the lubricating film during bearing operation. The active part of the film, too thin to fluoresce visibly, averages ten-millionths of an inch in thickness.

Circle 2125 on Page 48-B

2 IMPORTANT DEVELOPMENTS in PRECISION METALLURGY from . . . CARL ZEISS JENA



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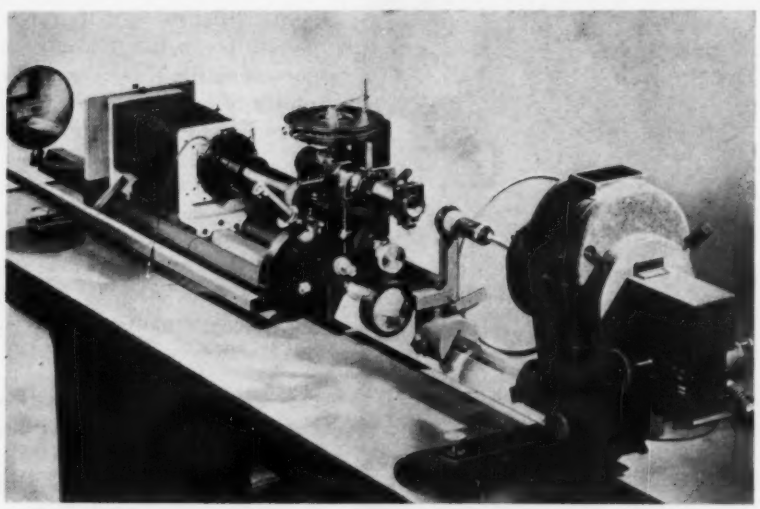

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whether 125, 5000, 30,000 or 100,000 psi

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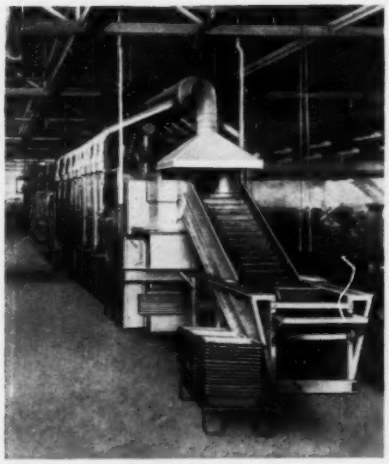

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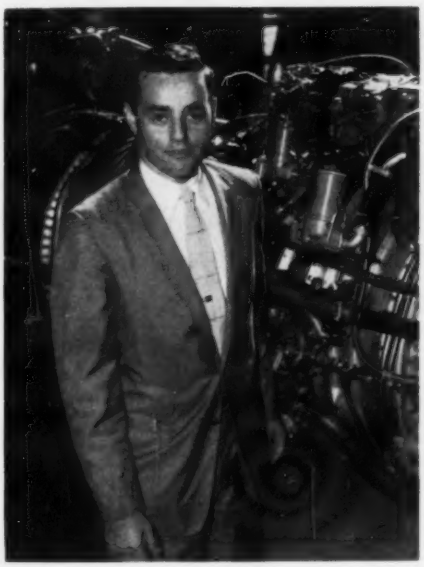
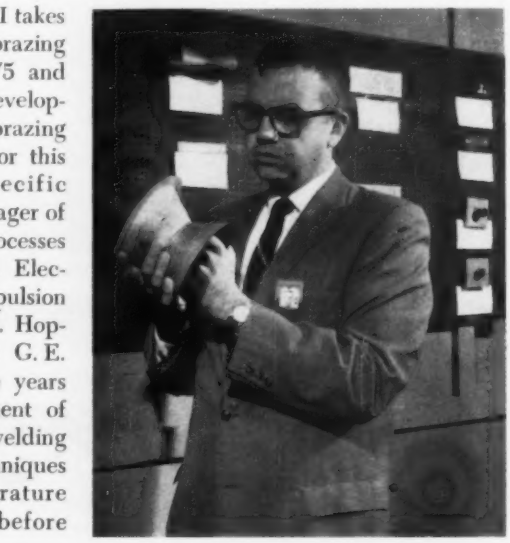
BEHIND THE BYLINES

Leading off this month's section on progress in high-temperature metals is an article on one of the newest of the superalloys, René 41 (p. 70). Details on heat treating, welding and brazing are given by Louis A. Weisenberg and Robert J. Morris. Mr. Morris, formerly with G.E. and now with International Nickel Co., is a frequent author for Metal Progress (see Behind the Bylines, *Metal Progress*, December 1959, p. 231). Mr. Weisenberg recently joined G.E.'s Jet Engine Department after completing an assignment at the Knolls Atomic Power Laboratory. Since joining the company in 1956, he has been concerned with the development and application of high-temperature materials for jet engine and nuclear power plant components and, primarily, with René 41.



A graduate of the Michigan College of Mining and Technology, he worked on metallurgical production engineering in the iron mining industry and the aeronautical division of Minneapolis-Honeywell Regulator Co.

His wife and two sons share his enthusiasm for outdoor sports and bowling.



G. S. Hoppin III takes a closer look at brazing René 41 on p. 75 and describes the development of three brazing alloys designed for this superalloy's specific needs. Now manager of metallurgical processes units in General Electric's Flight Propulsion Department, Mr. Hoppin's work with G. E. has included five years on the development of new brazing, welding and forming techniques for high-temperature materials and before

that two years' work on failure analysis and other metallurgical investigations.

After graduating from the University of Michigan with a B.S. degree in metallurgical engineering, he operated the nondestructive testing laboratory for Chrysler Engineering for a year, then served two years in the Army.

The happy fellow on the right in the photograph below (taken at the 1960 Southern California Conference on Refractory Metals for Air and Space Vehicles, held under the sponsorship of the Los Angeles, San Diego and San Fernando chapters of A.S.M.) is our consulting editor Robert H. Gassner whose report of the conference appears on p. 80. He's showing one of the name plates used at the

conference to F. K. Lampson of Allegheny Ludlum Steel Co. and H. A. Curwen of Earle E. Jorgensen Co. No ordinary nameplates, these were made of molybdenum sheet contributed by Universal-Cyclops and lettered by chem-milling by U.S. Chemical Milling. Mr. Curwen was recently named convention chairman for the 12th Western Metal Congress, scheduled for March 20 through 24, 1961, in Los Angeles.

"Modified 4340, Heat Treated to 270,000 to 300,000 Ultimate", by J. C. Chang, F. J. Herr and J. W. Sweet (see p. 104), all of Boeing Airplane Co. in Seattle, is the first of two articles on modified 4340. Mr. Chang studied metallurgy in China, receiving a degree in mining and metallurgical engineering from Chiao Tung University in 1942, and continued his studies at the University of California, where he obtained his master's in metallurgy in 1948. He came to Boeing's metals unit as a junior engineer and for the past two years has worked as a research engineer. (Mr. Chang is shown on p. 218, left, with his fellow authors, Messrs. Sweet and Herr.) Mr. Herr has been with the metals unit for eight years. A Carnegie Institute of Technology graduate, his background includes work in metal-

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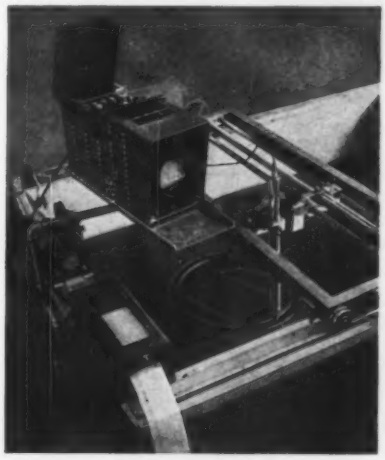

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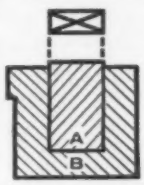

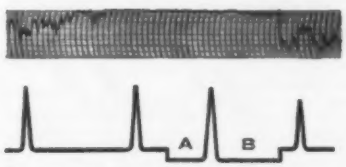

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Circle 2130 on Page 48-E

Behind the Bylines . . .

lurgical laboratories and as sales and service metallurgist for several large steel companies including Jones & Laughlin Steel Co., Vanadium Alloys Co. and Latrobe Electric Steel Co. Mr. Sweet, the senior author of the three, came to Boeing 25 years ago, after his graduation from the University of Washington, to work on engineering design. He was placed in charge of the metallurgical laboratory of the Renton plant in 1942 and since 1946 has been chief metallurgist.

O. E. Cullen, author of "Quenching in the Automatic Production Line" on p. 101, is manager of research and development and chief metallurgist of Surface Combustion Div. of Midland-Ross Corp., Toledo, Ohio. A University of Detroit graduate in metallurgical engineering, he was a research engineer for General Reduction Corp. in Detroit for several years before coming to Surface Combustion in 1936. As a research and development engineer, he specialized in the development and operation of industrial heat treating furnaces for the processing of ferrous and nonferrous metals. In 1942 he was named chief metallurgist and two years ago was given the added title and

responsibility of manager of research and development.

His extracurricular interests include technical societies – he's a member of S.A.E. and A.S.M. He was a member of the A.S.M. Handbook Committee from 1951 to 1954 and on the National Vocational Education Committee. He also has served as a University Lecturer in metallurgy for a number of years.

Our cover story on stress analysis with a photoelastic coating is by Felix Zandman, director of basic research for the Budd Instruments Div. (formerly Tatnall Measuring Systems Co.) in Phoenixville, Pa.

Dr. Zandman studied metallurgical engineering at the University of Nancy (France), then went on to graduate studies in general physics and in applied mechanics at Nancy. He received his doctorate from the University of Paris, Sorbonne, studying strain behavior of plastics and crystal dislocation in metal due to fatigue stresses. While in France, he was chief of the stress analysis laboratory and chief of the research section for a jet engine factory and professor of stress analysis at the Engineering School of Aeronautics in Paris for two years. He was technical director of PhotoStress Inc., before joining Budd in 1957.

Tom Bishop, our consulting editor based in London, made a quick trip to Paris late in May to report a conference by an international group of metallurgists and testing engineers on the shaping of metal and tests to determine formability, organized by the International Deep Drawing Research Group and the Société Française de Métallurgie. Like all good visitors to a foreign city, he sent off some postcards – we received the one above, with the touching message: "Hard work, these conferences!" The picture postcard shows a tired Parisian–not, as one might possibly think, an exhausted *Metal Progress* Consulting Editor.

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Circle 2131 on Page 48-B

ADVERTISERS INDEX

Acheson Colloids Co. 22
Air Reduction Sales Co. 147
Ajax Electric Co. 123
Ajax Magnethermic Corp. ..... **Inside Front Cover**
Aldridge Industrial Oils, Inc. 187
Allegheny Ludlum Steel Corp. 100C
Allied Research Products, Inc. 151B
Alloy Engineering & Casting Co. 31
Alpha-Molykote Corp. 43
American Bridge Div., United States Steel Corp. 202-203
American Gas Association 179
American Gas Furnace Co. 197
American Machine and Metals, Inc., Riehle Div. 20
American Optical Co. 140
American Smelting & Refining Co. 33
American Society for Metals 46, 208, 211
Anaconda American Brass Co. 173
Armco Steel Corp. 175
Armstrong-Blum Mfg. Co. 166
Asea Electric, Inc. 189
Ashworth Brothers, Inc. 138

Babcock & Wilcox Co., Refractories Div. 18-19
Baldwin-Lima-Hamilton Standard Steel Works 51
Barber-Colman Co., Wheelco Instrument Div. 50
Bausch & Lomb Optical Co. 100D
Bethlehem Steel Co. 17, 204
Bishop & Co., J. 196
Bix Co. 188
Branson Instruments, Inc. 217
Branson Ultrasonic Corp. 188
Bristol Co. 56, 168
Brooks & Perkins, Inc. 154
Brush Beryllium Co. 40
Budd Co. 139, 218
Buehler, Ltd. 6

Cambridge Wire Cloth Co. 159
Cannon-Muskegon Corp. 195
Carborundum Co., Globar Div. 171
Refractories Div. 210
Carl Mayer Corp. 45
Carpenter Steel Co. 125, 151A
Chambersburg Engineering Co. 134
Cleveland Alloy Castings, Inc. 141
Consolidated Electrodynamics Corp. 27
Consolidated Vacuum Corp. 219
Copperweld Steel Co. ..... **Back Cover**

Detrex Chemical Industries, Inc. 143
Detroit Flame Hardening Co. 181
Dietert Co., Harry W. 142
Drever Co. 42

Eastern Stainless Steel Corp. 155
Eastman Kodak Co., Graphic Reproduction Sales Div. .. 39
Industrial X-Ray Div. 131
Eclipse Fuel Engineering Co. 188
Electra Products Co. 181
Electric Furnace Co. .. **Inside Back Cover**
Electro-Alloys Div., American Brake Shoe Co. 2
Elgeet Optical Co., Inc. 129
Engineered Precision Casting Co. 186
Englehard Industries, Inc., National Electric Instrument Div. 39
Ercona Corp. 214

Fenn Manufacturing Co. 132
Finkl & Sons Co., A. 146
H. B. Fuller Co. 185

Garden City Fan and Blower Co. 188
General Alloys Co. 44
General American Transporation Corp. 200
General Electric Co., Apparatus Sales Div. 190
X-Ray Department 151
General Extrusions, Inc. 184
General Motors Corp., Research Laboratories 213
Glenn-Pacific Power Supply Co. 153
Globe Steel Abrasive Co. 169
Great Lakes Steel Corp. 162-163
Gries Industries, Inc. 182
Grieve-Hendry Co., Inc. 187

Hacker, Wm. J., and Co., Inc. 181
Haller, Inc. 182
Hamler Industries, Inc. 167
Handy & Harman 14
Harris Manufacturing Co., Inc. 174
Harrop Precision Furnace Co. 211
Hayes, Inc., C. I. 34
Haynes Stellite Co., Div. of Union Carbide Corp. 177
Hevi-Duty Electric Co. 8-9
Holcroft & Co. 216
Hooker Chemical Corp. 52-53
Hoover Co. 184
Hoskins Manufacturing Co. 128
Houghton & Co., E. F. 192-193
Hull & Co., Inc., R. O. 176
K. H. Huppert Co. 183

Illinois Testing Laboratories, Inc. 136
Indium Corp. of America 211
Induction Heating Corp. 29
International Nickel Co. 100A, 194, 207
Ipsen Industries, Inc. 16

Jarl Extrusions, Inc. 182

Kent Cliff Laboratories Div., Torsion Balance Co. 184
King Tester Corp. 154
Kocour Co. 186

Lake Chemical Co. 185
Latrobe Steel Co. 137
Leeds & Northrup Co. 127
Leitz, Inc. 30
Lindberg Engineering Co. 36
Linde Co., Div. of Union Carbide Corp. 58-59
Lindsay Chemical Div., American Potash & Chemical Corp. 172
Lithium Corp. 212
Little Falls Alloys, Inc. 185
Loma Machine Manufacturing Co. 5
Lucifer Furnaces, Inc. 184
Lunex Co. 41

Magnaflux Corp. 183
Magnetic Analysis Corp. 187
Malleable Castings Council 148, 149
Markal Co. 180, 181
Minneapolis-Honeywell Co. ..10-11, 32

National Carbon Co., Div. of Union Carbide Corp. 26, 209
National Ultrasonic Corp. 183
Newage Industries, Inc. 185
Nordson Corp. 174
Norton Co. 47
NRC Equipment Corp. 7

Oakite Products, Inc. 191
Ohio Crankshaft Co. 150

Pangborn Corp. 62-63
Pereny Equipment Co. 205
Perkin-Elmer Corp., Instrument Div. 158
Picker X-Ray Corp. 135
Pressed Steel Co. 25

Radio Corp. of America 133
Ramco Equipment Corp., Randall Mfg. Co. 185
Reese Metal Products Corp. 181
Republic Steel Corp. 54-55
Revco, Inc. 41, 186
Riehle Div., American Machine and Metals, Inc. 20
Riverside-Alloy Metal Div., H. K. Porter Co., Inc. 156
Rolled Alloys, Inc. 183
Rolock Inc. 126
Rust-Lick, Inc. 182
Ryerson & Son, Inc., Joseph T. 64

St. Joseph Lead Co. 198
Salem-Brosius, Inc. 38
Sandvik Steel, Inc. 130
Scott Testers, Inc. 188
Selas Corp. 206
Sherritt Gordon Mines Ltd. 4
Shore Instrument & Mfg. Co., Inc. 187
Sieburg Industries, Inc. 187
Sifco Metachemical, Inc. 164
Sorgel Electric Co. 184
Spencer Turbine Co. 145
Stanwood Corp. 182
Star Stainless Screw Co. 186
Steel City Testing Machines, Inc. 23
Stokes Corp., F. J. 60-61, 164
Superior Tube Co. 215
Surface Combustion Div., Midland-Ross Corp. 12-13

Technic, Inc. 186
Tempil Corp. 157
Texaco Inc. 160-161
Thermo Electric Co., Inc. 142
Timken Roller Bearing Co. 165
Torsion Balance Co., Kent Cliff Laboratories Div. 184

Union Carbide Metals Co. 57
Unit Process Assemblies, Inc. 185
Unitron Instrument Co. 49
Universal-Cyclops Steel Corp. 199

Vanadium Alloys Steel Co. 15
Vanadium Corp. of America 48

Westinghouse Electric Corp. 24, 178
Wheelco Instrument Div., Barber-Colman Co. 50
White Metal Rolling & Stamping Corp. 184
Wilson Engineering Co., Inc., Lee 201
Wilson Mechanical Instrument Div., American Chain & Cable Co. 144, 187
Wiretex Mfg. Co. 182

Yoder Co. 158

Zak Machine Works, Inc. 28
Zirconium Corp. of America 45
Ziv Steel & Wire Co. 43

KABLE PRINTING COMPANY

View of One Bay in the New Research Building
Showing the Continuous Strip and Bell Furnaces.

THE ELECTRIC **EF** FURNACE CO.

GAS • OIL • ELECTRIC

completely equipped
Research Department

to develop and test improved heat treating techniques benefitting ALL metal producers and fabricators . . .

From the company's earliest beginning research has been traditional at The Electric Furnace Co.

Recently our facilities have been much enlarged. Our research department now has its own building, 180 feet long by 80 feet wide. Equipment includes a continuous strip furnace suited for processing at various cycles; bell, wire mesh belt, batch and pusher furnaces, with and without forced circulation; vacuum furnaces for batch or continuous operation; endothermic and exothermic generators; ammonia dissociators; atmosphere refrigerators; adsorption type gas dryers; CO_2 scrubbers, and completely equipped chemical and metallurgical laboratories.

From these larger facilities are coming improved techniques for treating the familiar materials, and new techniques for treating the newer metals of the jet and space age;— also expanded testing of critical materials used in our furnaces, to maintain our unsurpassed standards of quality and performance.

As in the past, our research facilities will be available to **all** metal producers and processors, for development and test work, conducted, if desired, in the presence, and with the assistance of your own technical men.

This complete and modern laboratory is as close to you as your telephone. Feel free to use it frequently!

EF

THE ELECTRIC FURNACE CO.

Gas-fired, Oil-fired and Electric Furnaces for Heat Treating any Product, Using any Process, any Hourly Output.

200 West Wilson Street *Salem - Ohio*

SUBSIDIARIES — Turnkey Engineering Company, Inc., South Gate, California • Canefco Limited, Scarborough, Ontario
ENGINEERING & SALES REPRESENTATIVES — 2842 West Grand Blvd., Detroit 2, Michigan and 968 Coleman Rd., Cheshire, Conn.

Circle 1991 on Page 48-8

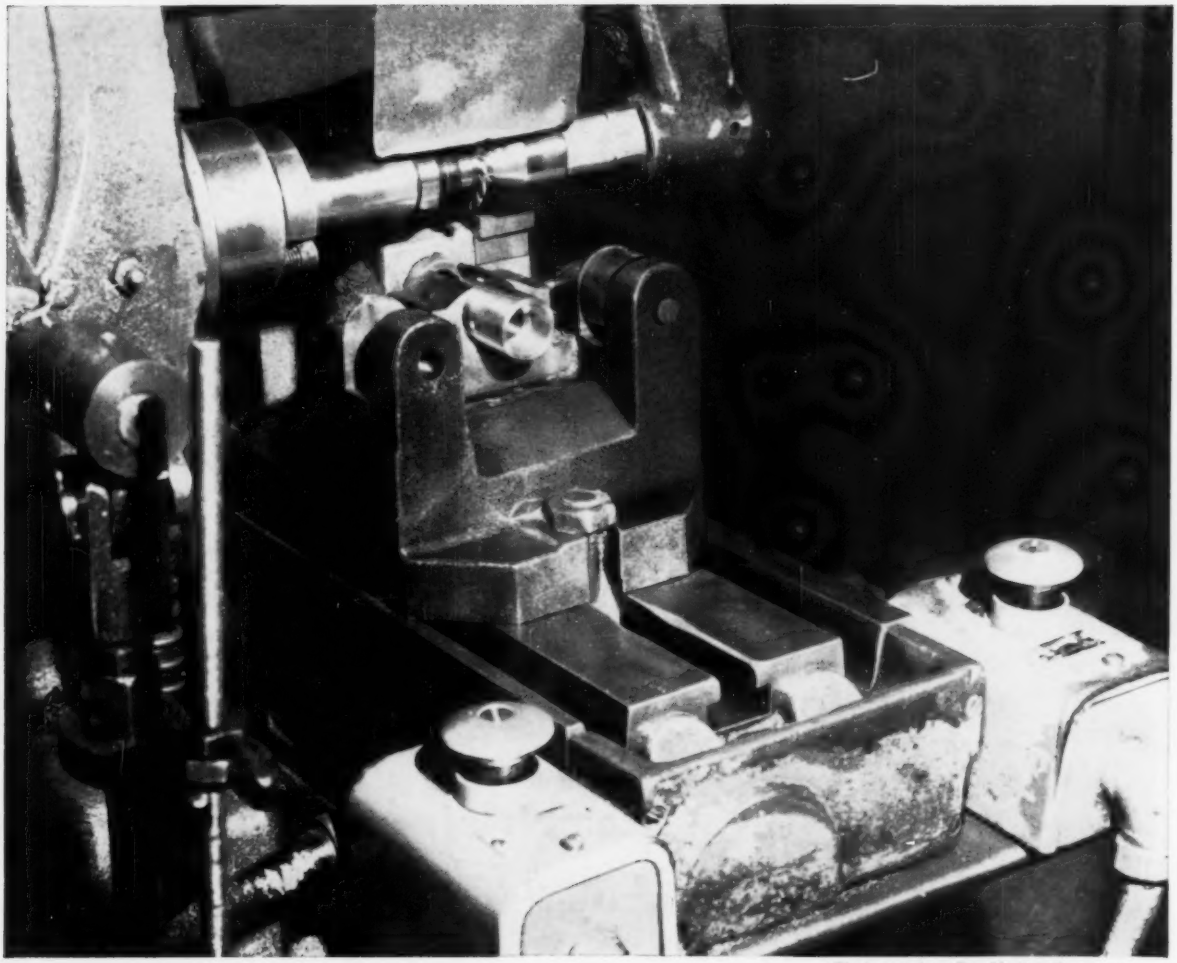

Photo courtesy The Maytag Company

Aristoloy Leaded 8620 cuts tool changes 50% on wringer drive sleeve for Maytag

Has working time been reduced? Yes.

In what way? The use of Aristoloy Leaded* has increased tool life and reduced downtime for tool changes.

Has machining been improved? Yes.

What inherent quality in the steel is responsible for improved machining? A more uniform, satisfactory microstructure provides better machining characteristics.

What operation is performed? Automatic screw machines bore, counterbore and cut off. Secondary operations include milling, drilling, internal and external grinding after carburizing.

For complete information about Aristoloy blooms, slabs, billets and bars, in carbon, alloy, stainless and leaded, call the Copperweld representative in your nearest large city—or write for NEW PRODUCTS & FACILITIES CATALOG.

*Inland Ledloy License

ARISTOLOY STEELS

DIVISION OF
COPPERWELD STEEL COMPANY

ARISTOLOY STEEL DIVISION • 4013 Mahoning Ave., Warren, Ohio • EXPORT: Copperweld Steel International Co., 225 Broadway, New York 7, N. Y.

Circle 1992 on Page 48-B